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Erection Appliances for the Belly River Viaduct at Lethbridge, Alberta.

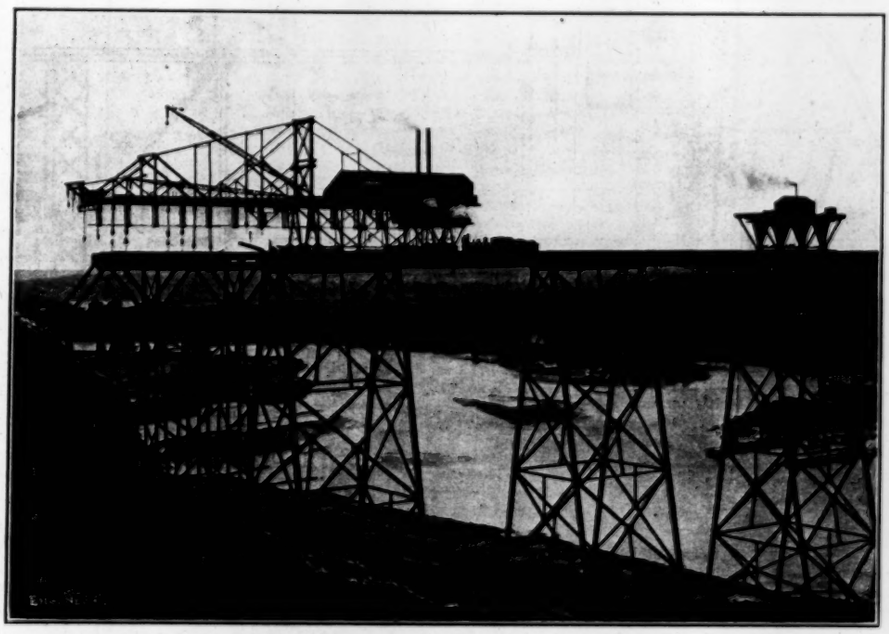
The erection of the high viaduct over Belly River, near Lethbridge, Alberta, on the relocated Crow's Nest branch of the Canadian Pacific Ry., gave occasion to use several interesting erection devices. Chief among them are a suspended assembling cage and bridges, which may be seen in the photographic view, Fig. 2, and a riveting traveler with suspended platforms. The manner of using these devices in conjunction with a heavy cantilever traveler was described in a paper by Mr. C. N. Monsarrat, Engineer of Bridges, Canadian Pacific Ry., read some weeks ago before the Canadian Society of Civil Engineers. The bridge itself was described by Mr. J. E. Schwitzer, Asst. Chief Engineer, in a paper reprinted in Engineering News of September 23, 1909, pp. 324-328.

STORAGE AND UNLOADING TRAVELER.—This viaduct, being not only high (307 ft. from river bed to base of rail), but also unusually long (5,327 ft.), contains so much steel as to make the storage and handling problem for erection material quite important. The storage yard, near the east end of the bridge, was provided with a steel traveling crane of 125-ft. span (Fig. 3), consisting of a 125-ft. through-truss highway span fitted with end carriages. The runway was built of wood. A hoisting engine geared to two of the end wheels was used for the longitudinal travel of the crane. At the center were hung two 6-part tackles, 17 tons capacity each, operated by a two-drum hoisting engine set on the crane. On each end of the crane was mounted a 5-ton stiff-leg derrick with 42-ft. boom, for storing light material alongside the runway. Thus a storage area 200 ft. wide by 240 ft. long was available.

The main part of the viaduct consists of 100-ft. plate-girder intermediate spans, and 67-ft. plate-girder tower spans, weighing, respectively, 30 tons and 15 tons. The former required to be shipped (in pairs, set close, spread to 8 ft. in the storage yard) on three 40-ft. flat cars each.

MAIN ERECTION TRAVELER.—The viaduct was erected by the aid of a cantilever traveler of 100-ft. overhang, a very heavy structure. Fig. 2 and the illustration above show this traveler at work. The drawing Fig. 1 gives its chief dimensions.

The two principal trusses of the traveler are 207 ft. long, 16 ft. apart (the same as the viaduct girders, as the traveler rode on their top flanges); 116 ft. of this length was overhung beyond center of forward truck. In addition to hoisting engines, boilers, etc., the rear end carried 30 tons of rails as counterweight. The whole traveler in working condition weighed 356 tons.



MAIN TRAVELER SETTING MEMBERS OF TRUSS SPAN OVER BANK.

The deck of the traveler was set high enough to permit loaded flat cars to pass through beneath. The trusses carried two longitudinal trolley-tracks 8 ft. apart, on which ran four trolleys for picking up material from the cars. A 40-ton hydraulic jack, 18 ins. stroke, hung from each trolley, to lift the material. This arrangement made the minimum demand on head room. When a pair of girders had been lifted off the cars, the trolleys were run forward with their load, until vertically over the place where they were to be lowered. Then manila rope tackles slung from the truss chords were attached (see cross-section in Fig. 1), the load taken off the jacks and the girders allowed to spread to 16-ft. spacing and lowered to place. Lighter material was handled directly by rope tackle hung from the trolleys and usually was lowered to the ground, except that floor material was set directly.

Two 85-ft. derrick booms were set on the traveler, one on each side over the forward truck, and guyed back to the top chord of the trusses. These raised the longitudinal bracing of the towers from the ground. Bracing in the plane of the bents was raised by rope tackle hung at the end of the cantilever.

The trolley travel and trolley tackle were handled by a 6-spool hoisting engine on the mezzanine platform at the rear of the traveler. The other tackles, the derrick ropes, the erection cages, etc., were handled by two 6-spool and three double-drum engines, and a special 12x14-in. engine with extra large drums for lowering to the ground the heavy column sections (33,000 lbs. maximum). These six engines were set on the main deck of the traveler.

ASSEMBLY CAGE.—This novel device was employed in connecting the transverse bracing of each bent. As shown by Figs. 1, 2 and 4, it consisted of three narrow platforms, spaced vertically so as to command the top, middle and bottom of one story of the bent, connected by hangers and bracing; the whole cage, weighing 40,000 lbs., was suspended from the end of the traveler, and for lateral steadiness was lashed to the columns. The cage was 111 ft. in greatest breadth, 47 ft. high and about 4 ft. wide. Two 7-part tackles of ⅞-in. rope were used to support it. From this structure the lateral bracing was connected and bolted, and also the succeeding sections of column side-hauled and set. For the latter purpose ⅝-in. rope tackles were fastened at the extreme ends of the middle platform, and lines run thence to one of the traveler hoisting engines. The operation of side-hauling is illustrated in Fig. 1.

A telephone on the assembling cage connected with head sets worn by the several hoisting-engine operators was used for communicating. This method of signaling is said to have proved very effective.

ASSEMBLING BRIDGES AND BUCKETS.—Assembling bridges, similar to the main assembling cage, but having only one platform, were used in bolting up the longitudinal bracing of the towers. One of them may be seen on the ground in Fig. 2, while Fig. 1 shows the two (one on each side) in place. These bridges were set by the derrick booms and were fastened by bolting to the cover-plates of the columns, thus freeing the derrick lines.

Auxiliary to these bridges were assembling

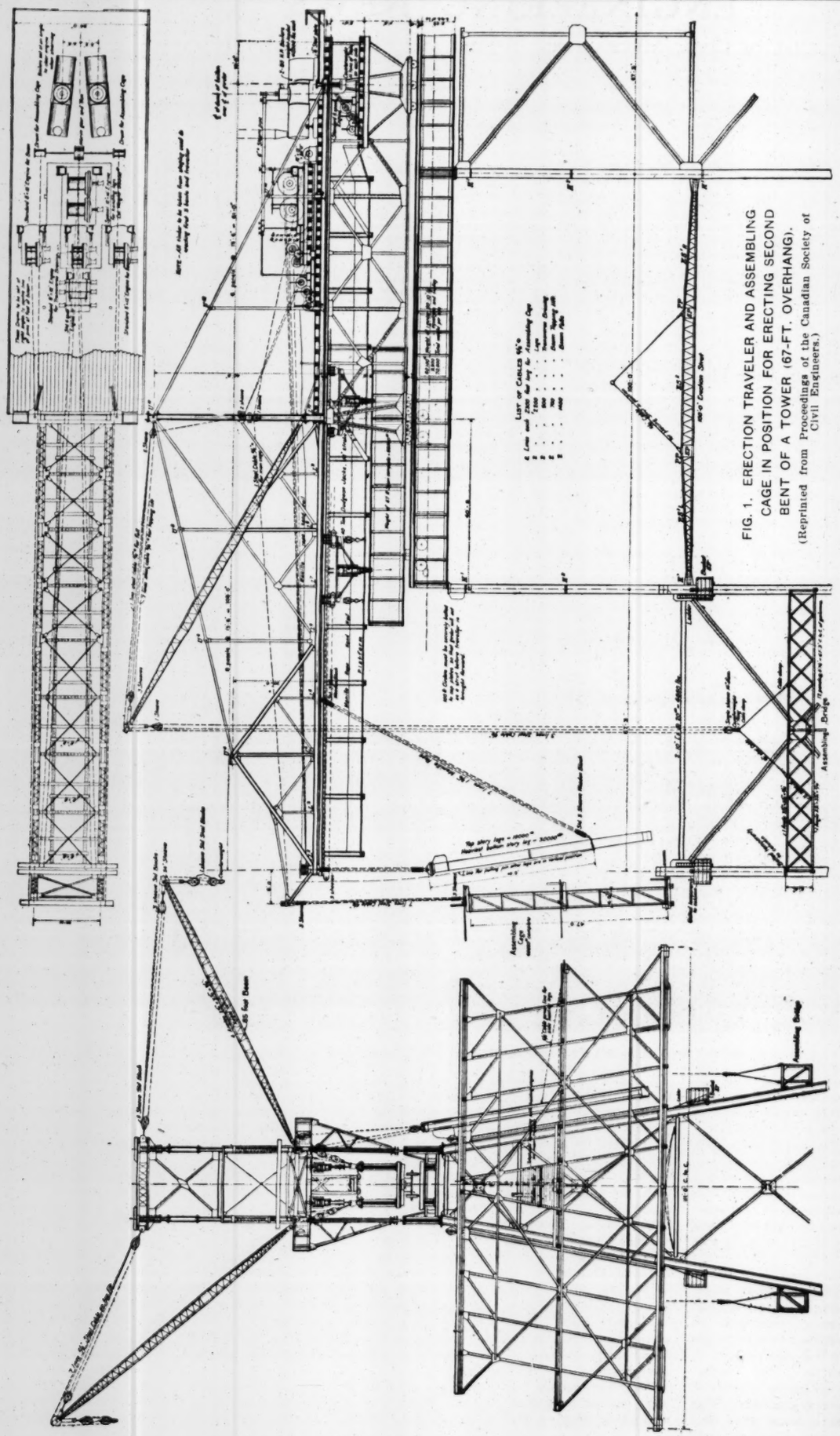


FIG. 1. ERECTION TRAVELER AND ASSEMBLING CAGE IN POSITION FOR ERECTING SECOND BENT OF A TOWER (67-FT. OVERHANG).
(Reprinted from Proceedings of the Canadian Society of Civil Engineers.)

buckets, consisting of an angle-iron frame with wooden sides and [illegible] and provided with a [illegible] ladder (see Fig. 1). They were also set by the derricks where needed and fastened to the columns with bolts. The bucks were used for connecting up the upper ends of the longitudinal diagonals and the ends of the longitudinal struts.

RIVETING TRAVELER AND BRIDGES.—A timber gallows-frame traveler ran along behind the main traveler, on the same track, for the purpose of carrying on each side a hanging platform similar to the above-described assembling bridges. Shorter platforms were also hung in the plane of each bent (the ropes passing through between the floor beams) for riveting the center connections of the transverse bracing. The side platforms were fitted with guide-wheels bearing against the tower posts. The two 7-part tackles which held each bridge went to worm-geared drums, to make the bridges absolutely safe against falling unless a rope or fastening broke. This traveler was about 90 ft. long over its top frame, to be able to hang the small platforms in both bents of a tower simultaneously. The running gear comprised three two-wheel trucks on each side, spaced 40 ft. c. to c. of front and rear trucks. This traveler, like the main traveler, straddled the viaduct track at a sufficient elevation to allow loaded cars to pass under it.

PNEUMATIC RIVETING.—There were some 328,000 field-rivets in this viaduct. All were driven by pneumatic riveting hammers. Compressed air at 100 lbs. was produced by a compressor plant on the ground near the commencing end of the structure and was piped out by steel pipe to the riveting traveler. From this point flexible hose led down to the platforms.

PROGRESS OF ERECTION.—The first three spans at the east end were erected before the traveler was built. About the middle of August, 1908, the traveler began erecting steel. Time was lost in winter through cold and stormy weather and through a strike, but the last span was completed before the first of July, 1909. The fastest work was done during March, 1909, when 735 lin ft. of structure near the highest portion were erected complete, comprising 10 bents.

Fig. 2. Assembling Cage Working on Bottom Story of a Tower of Lethbridge Viaduct.

All this work was erected in the manner shown by the illustrations, except that the 167-ft. truss span over the bank at the west end was erected on falsework.

The structure included 12,200 tons of steel; in the substructure are 1,676 concrete piles and 17,090 cu. yds. mass concrete.

It is worth mention that an overhead inspection traveler has been designed for giving facilities for inspection and painting. This will carry suspended cages, like the riveting traveler, operated by a hoisting engine set on the traveler.

The bridge was designed in the office of C. N. Monsarrat, Engineer of Bridges, Canadian Pacific Ry., with the assistance of Mr. C. C. Schneider as Consulting Engineer. The Canadian Bridge Co., of Walkerville, Ont., fabricated and erected the steel; Mr. J. W. Stoughton was Superintendent of Erection, and Mr. C. F. Prettie was Superintendent on the ground. Mr. J. Rankin was Resident Engineer for the railway company.

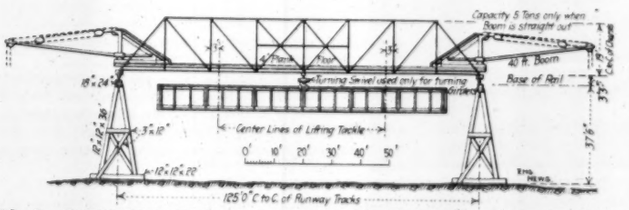

Capacity 5 Tons only when Boom is straight out
40 ft. Boom
Base of Rail
Turning Swivel used only for turning Gantry
Center Lines of Lifting Tackle
0' 10' 20' 30' 40' 50'
125'0" C to C. of Runway Tracks

FIG. 3. OUTLINE SKETCH OF UNLOADING TRAVELER OVER STORAGE YARD NEAR EAST END OF LETHBRIDGE VIADUCT.

DEFINITION OF INDUSTRIAL TERMS.—At the recent annual meeting of the Division of Industrial Chemists and Chemical Engineers of the American Chemical Society, a committee was appointed to formulate definitions, of trade products, which shall be accurate, fair and consistent. This committee was appointed at the request of several parties who desired authoritative definition of terms like "gasolene," "gasoline," "benzene," "benzine," "benzol," "bronze," "steel," "cement," etc., etc. The committee consists of Messrs. Clifford Richardson (Chairman), J. B. F. Herreshof, and G. P. Adamson. This committee desires to receive suggestions from all who are interested in the subject, and their comments on the terms, in the various branches of industry, which are considered most in need of closer definitions. Definitions now approved by the Industrial Division of the American Chemical Society will be recognized as authoritative. Communications should be addressed to Mr. Richardson at 30 Church St., New York City.

The Training of Men as a Part of a Modern Factory System.*

By M. W. ALEXANDER,† M. Am. Soc. M. E.

Emerging from the depression of the last two years, American industries are once more entering upon an era of prosperity, which in the natural course of events should surpass in magnitude and intensity anything yet seen in the industrial world. One obstruction alone lies in the path of this unrivaled future: lack of men to do the work is a fact that confronts keen observers of the situation. Only a few years ago the cry for efficient men in all branches of industrial activity was universal and insistent, and manufacturers everywhere complained of their inability to man their establishments properly. Skilled mechanics were at a premium. Capable industrial foremen and superintendents were painfully scarce. Positions of leadership calling for men of education, experience, and breadth of view could be filled only with difficulty. The industrial depression of 1907-1908 naturally relieved the embarrassment; but even then skilled mechanics and efficient foremen could not be secured in adequate numbers. The last few months have already clearly demonstrated that the acuteness of the situation has returned, and that this condition will be accentuated as time goes on.

Now is the time to analyze the situation, and, in the light of our experience, work out a comprehensive policy which will enable us to cope with the exigencies as they arise. This is a matter which concerns every manufacturer, large and small; it is as much a problem of business sagacity as of immediate necessity.

In December, 1906, I had the privilege of presenting to the American Society of Mechanical Engineers my ideas concerning the training of young men for positions as skilled mechanics and foremen, and of showing how this scheme had been put into practical operation through the apprenticeship system of the General Electric Company at West Lynn, Mass. In the meantime this system has been materially extended so as to provide adequately for the boy with a grammar-school, a high-school, or an engineering-college education. New lines of factory work have been included, and cognizance has been taken of the necessity for training machine specialists. The educational scheme of the Lynn Works, therefore, presents in its present scope a comprehensive policy. The underlying thought of all this training is the belief that skill will demonstrate its full potential value only as it is supported by intelligence. Each course of training, except in the case of machine specialists, includes, therefore, distinctive educational work, and the scope of each course is based on the previous education of the individual. There are, of course, young men of pronounced native ability, who, no doubt, would prove to be efficient in training courses from which the above education requirement excludes them, but to deal with these exceptions would complicate the process of selection and the system of training.

TRAINING MACHINE SPECIALISTS.—In the training courses for trade apprentices alone, which are ordinarily open to grammar-school graduates only, boys with an incomplete grammar-school education, who can pass a satisfactory examination, may be admitted; in all other courses rigidity of requirements is necessarily maintained.

In the training leading to positions as machine specialists, such as shaper, lathe and boring mill hands, milling machine operatives, etc., no provision has yet been made for educational advancement as distinctive from training for skill. This can be effected at any time, however, without undue expenditure.

The company recognizes the existence of workingmen who are in the class of unskilled labor from lack of opportunity or of foresight or due to other circumstances not under their control and for the same general reasons remain in such service. Many, of course, by disposition and general makeup, are bound to find their livelihood in such unskilled labor, while on the other hand, many can be trained in a comparatively short time to semi-skilled and skilled special work. Such training will increase their economic value and their contentment and add materially to the productive efficiency of the factory. In pursuance of this policy a systematic effort is made to select, from among the unskilled workers, men of from 20 to 35 years of age who give fair promise of success as machine specialists. Some of these men are now receiving instruction in lathe work, others in shaper or boring mill, or planer or milling-machine work. This training lasts from three to four months, depending on individual capacity, and the men receive during that time an hourly rate which gives them a living wage. A capable instructor makes the selection, assigns the men to the various factory departments where machines and work are available, and supervises their training. These men are, of course, under the foremen in whose department they are working for the time being, but the instructor, who is a very capable skilled mechanic, having had charge of men for many years, visits them almost daily and sees that they receive work of an instructive character and of advancing difficulty, as far as this can be done without undue interference with the productive requirements of the factory. When the instructor is satisfied with a man's capability of handling his machine and of turning out a fair amount of work, he assigns him permanently to a foreman who requires such service. The machine specialist then takes his place as a regular workman and receives regular day or piece-work compensation. The same man, however, may apply again to the instructor for special training on some other machine; thus gradually fitting himself for a position as all-around machinist and tool-maker, with correspondingly higher compensation.

An arrangement of this kind entails no material hardship on anyone, gives many men an opportunity to rise to a higher plane of efficiency, automatically supplies the factory with capable machine specialists, and tends to attract to the factory men of ambition and stamina. This work might be further extended by giving to those who cannot sacrifice the temporary reduction of wages, an opportunity to receive their training during evening hours and on Saturday afternoons. This problem was outlined in my paper, "A Plan to Provide for a Supply of Skilled Workmen" (Transactions, Am. Soc. M. E., Vol. 28, p. 439).

TRAINING OF FOREMEN, DESIGNERS, ETC.—Far more comprehensive in scope, and covering a longer period of time, must of course be the training of those who are to take positions as highly skilled mechanics and foremen, designers and engineers, superintendents and managers. The industries themselves must furnish this training, inasmuch as our school systems do not provide for it to-day, and very likely in the future will be able only to approach the full requirements. Mental training closely correlated with practical instruction may be gained by putting both under the sole charge of the factory management; or smaller factories may combine for joint classroom instruction; or the theoretical instruction may be delegated entirely to public school authorities, who could provide special classes for instruction alternate days or weeks. All three schemes are in operation to-day, and any one will prove effective if properly managed, and if selected with reference to local conditions, size of factory and available personnel.

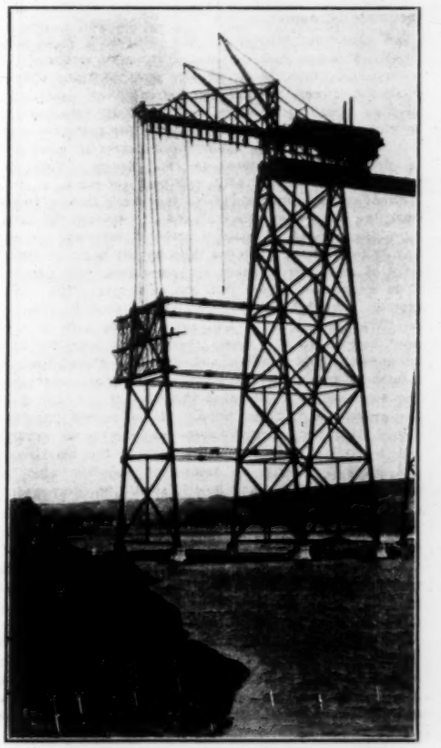


Fig. 4. Main Traveler and Assembling Cage During Erection of Tower.

*A paper printed in the Journal of The American Society of Mechanical Engineers, January issue.
†General Electric Co., Lynn, Mass.

Apprentice Systems at the West Lynn Works of the General Electric Co.

A bare outline of the system established by the General Electric Co., at West Lynn, which was fully treated in my former paper, may be of interest as showing how it has developed in the last three years, during which time about 100 apprentices have graduated from the course.

REGULAR APPRENTICE TRAINING.—Boys of at least 15 years of age, who have had a grammar school education or its equivalent, may be admitted on completion of a two months' trial period, to the regular apprentice course. It is largely contended by manufacturers that boys under 16 are not fit for trade training. A normally bright boy, however, unless he goes to high school, will usually be obliged to seek employment at 15, and it is better for him to be put immediately under systematic trade instruction. Naturally, the work at the beginning must be suited to the boy's immature physical as well as mental development, and boys lacking in physical strength will be accepted neither at 15 nor at 16 years of age.

The training for future tool and die makers, instrument makers and pattern makers, lasts four years, while iron, steel and brass molders, blacksmith and steam-fitter apprentices, who should be somewhat older and stronger, receive three years of training. The two months of trial are included in this period. Apprentices receive compensation, even during the trial period, at the rate of 8 cts. per hour for the first six months, 10 cts. for the second six months, 12 cts. for the second year, 14 cts. for the third year, and 16½ cts. for the fourth year. Molder, blacksmith and steam-fitter apprentices, on the other hand, receive 10 and 12 cts. per hour respectively for the first and second six months' periods, 14 cts. for the second year, and 16½ cts. for the third year. In either case satisfactory completion of the course entitles the graduate to a Certificate of Apprenticeship and a cash bonus of $100. The normal number of working hours is 55 per week.

The average compensation paid to graduated apprentices is $2.75 per day, although some are started at $3 a day immediately upon graduation. The significance of these figures is more fully appreciated when it is borne in mind that the young man 21 years old receiving such pay is only just beginning his life's work, with a solid preparation for marked future advancement.

All apprentices are obliged to spend from an hour and a half to two hours in the classrooms every day except Saturday, except during part of July and August, when instructors and apprentices may take their vacations. Classes meet during regular working hours, usually at the beginning or end of the half-day periods. Full compensation is paid during classroom hours. Retention on the course and the payment of the bonus are dependent on satisfactory work in the classroom as well as in the shop, and the standing in both is stated on the Certificate of Apprenticeship.

The classroom instruction is based on a grammar-school education, and includes arithmetic, algebra, geometry and trigonometry, physics as it concerns simple machines, power transmission, strength of materials, machine design, magnetism and electricity, mechanical drawing, and jig and fixture design. For pattern-maker and molder apprentices an extended course in mechanical drawing is substituted for tool design. This instruction is practical, with constant reference to the work of the apprentices and to the usual factory problems, the aim being, above all else, to develop the ability to reason and to foster a pride of vocation. In no way is this stimulated more than by the daily practical talks of the superintendent of apprentices, who carries, so to speak, the factory into the classroom. The many answers offered by the apprentices to such a question as, "Why does a 1-in. drill cut a larger hole in cast iron than in steel?" reveal their mental capacity and mechanical understanding and give the superintendent a splendid opportunity for driving home practical truths. The superintendent continues this kind of instruction in the apprentice training room. If he notices, for instance, that an apprentice uses an improperly ground tool, he calls a number of the boys to the blackboard and explains clearly by means of sketches what is wrong about the tool and how it should be sharpened.

THE APPRENTICE TRAINING ROOM.—The training room is a special department for apprentices, a trade school in the factory, with this distinction, however, that all work is commercial work selected solely for its instructive character. It had its inception in the belief that the apprentice should receive his initial training under the most favorable conditions and expert supervision. The very fact of this work being a part of the commercial output of the factory automatically insures a high standard of quality and quantity, and eliminates the false notions of these values usually found in purely educational trade schools. As a matter of record, the work of the apprentice is of a very high standard. Moreover, on work of a repetitive character, the apprentices attain a speed of from two-thirds to three-quarters of that of the average workman, and a quality of work fully equal to the average. On work generally classed as "tool work," the apprentices very closely approach and sometimes even equal the work of the skilled journeyman.

The reports of the general inspection department show that rejected motor shafts, for instance, average only 2% although the permissible limits for the journal and other parts of the shaft are usually not more than 0.0005 in., and in any event not more than 0.001 in. Other work requiring accuracy to micrometer measurements is equally creditable to the apprentice training. Wherever possible, jigs made by the apprentices are not allowed to leave the training room unless the accuracy of the work has been proved by drilling or machining a part for which the jig was made. Several molds for various materials have been recently finished in the apprentice training room and the accuracy of the work proved not only by the pieces molded, but also by the fact that the parts of the various molds could be accurately assembled in the different permissible combinations.

Training rooms have been established for tool-maker and pattern-maker apprentices, occupying departments of about 15,000 sq. ft., and 4,000 sq. ft., respectively. No training room has yet been organized for molder apprentices, as there are only a few of them and as this part of the system is not yet very far developed. The training rooms are in charge of expert mechanics who act as assistant foremen to the superintendent of apprentices. One assistant takes care of about 25 apprentices in the pattern training room, and four assistants look after the business conduct of the machinist training room, with the instruction of about 130 apprentices. The small number of instructors and supervisors is explained by the arrangement under which the apprentices themselves, at various stages, act as instructors to those less advanced. In this way, not only is the instruction carried on with economy, but latent ability for executive work is developed and the apprentices are taught self-reliance much more quickly than if their every step was directed by journeyman instructors; the aim being to train skilled and intelligent mechanics, as well as to develop on this basis industrial foremen.

It is indicative of the individual instruction afforded, that frequently a pupil-teacher has served a shorter period of apprenticeship than the pupil he instructs. No course has been laid out for the practical work; each apprentice being advanced as fast as is consistent with his individual capacity. He must have a fair understanding of his machine and be able to produce his work with commercial accuracy and a fair degree of speed before he can be advanced.

The company believes that inasmuch as it pays good apprentice wages and offers excellent training and educational advancement, it is justified in expecting a high standard of workmanship and of deportment. Accordingly, a rigid weeding-out process takes place throughout the course; more than 50% of those serving the trial period are dropped at the end of two months and quite a few are discharged even after having signed the apprenticeship agreement. At first, a provision was made to send the apprentices to different departments in the factory, after about a year in the training room; later on, the time in the training room was extended to two years and the tendency now is to increase it to about three years before giving the apprentice a chance to acquire additional experience. The advantages of this arrangement lie not only in the extended systematic training of the apprentices, but also in their better general supervision during the most impressionable period of their lives. At times, of course, apprentices in all stages of training are loaned to factory departments for a few days or weeks; on the other hand, some of those who have already progressed into the factory are brought back into the training room, if the quantity or quality of their work, or their deportment, necessitates such disciplinary measures.

At the present time there are over 200 trade apprentices at the Lynn works, while 101 have already graduated. Of these 63 are now in the employ of the company, 8 serving as assistant foremen, 5 as inspectors and 12 as tool draftsmen, while the remainder work as skilled journeymen. Many of the latter, no doubt, will rise to positions of added responsibility during the next few years. The point is made clear to all apprentices, however, that a position as foreman or superintendent should not be the sole aim except for those with predominant executive ability. The percentage of graduates remaining with the company—in many respects a measure of the success of the scheme—varies, but it has never dropped below 55 and at times has been over 80.

DRAFTSMAN APPRENTICES.—No less encouraging are the results achieved with draftsman apprentices. Training for positions as draftsmen and designers is limited to young men with a complete high-school education who pass examinations in algebra, plane geometry and elementary physics. It has been found necessary to introduce this examination on account of the great divergence in the curricula of high schools and the great difference in scholarships among graduates. Accepted applicants must serve a two months' trial period satisfactorily before being indentured for an apprenticeship of three years at 10 and 12 cts. per hour respectively for the first and second six-month periods, 15 cts. per hour for the second year, and 2[illegible] cts. for the third year. They receive then a cash bonus of $75 and a Certificate of Apprenticeship which states their efficiency in practical and in theoretical work.

Draftsman apprentices are obliged to attend classroom exercises about an hour and a half every day except on Saturday and during part of July and August and a considerable amount of home study is required. The educational work consists of advanced algebra, descriptive and analytic geometry, plane trigonometry, advanced physics, inorganic chemistry, strength of materials and machine design. Instruction is for the most part of college rank, and college text books are used entirely, but again the closest correlation with the practical work in the shop and drawing office is maintained.

Examinations are held three times a year and failure to pass in all subjects with at least 70% necessitates the repetition of a 14 weeks' period. A second failure in the same subjects, or repeated failures in different grades, result in the discontinuance of the whole course. This does not necessarily mean that the delinquent must leave the company, for under certain conditions they are permitted to continue on the shop apprentice course under a four years' agreement. A few have already made this adjustment.

Draftsman apprentices receive machine-shop training during the first year and a half, and drafting instruction during the remainder of the three years' course. The machine-shop work is given principally in the apprentice training room on account of special facilities for this instruction. A part of the time, however, is devoted to repair work on machinery, and to tool work. The object is to give the future draftsman and designer an adequate insight into practical work so that he may appreciate in his designs the possibilities and limitations of the shop, and may, moreover, bear in mind the use of jigs and fixtures for economic manufacture on a large scale. The shop work, finally, inculcates in the young man an appreciation of the value of time and money such as he would not easily acquire without this training.

The work in the drawing office begins with a brief period of tracing, for the purpose of teaching the use of instruments, neatness, and the general arrangement of shop drawings; it continues on detail drafting and finishes with layout and design work. The high quality of the work of the apprentice is the natural consequence of the careful selection of applicants and the enforcement of a high standard of practical and educational achievement. Most of the young men are indeed a credit to the system.

The course for draftsman apprentices was originated about six years ago, but on a less ambitious plane. Grammar school graduates were then admitted for a four years training, and no particular stress was laid on educational instruction. It was soon found, however, that in this way good tracers and detail draftsmen could be developed, but not high-grade draftsmen and designers. About four years ago a high-school education was made an entrance condition, and a course of three years was offered. Soon after, class-room instruction was added, extending but slightly beyond a review of the high-school program. The apprentices who had been admitted under the less exacting requirements naturally fell behind and had to drop out, and the standard of the educational and drafting work was then gradually raised. In all 32 apprentices have been graduated under these conditions, most of whom have become competent draftsmen, while a few have started on promising careers as designers.

Still the company was not satisfied with the scope of the course. It was recognized that the general standing of a draftsman and the standard of his work had everywhere deteriorated during the last decade, largely on account of the great influx of superficially prepared draftsmen. To develop draftsmen and designers of pronounced capacity and intelligence would dignify the work and regain full recognition of its potential importance. Moreover, the graduates of the machinist apprentice course proved to be capable of developing into competent tool and mechanical draftsmen, so that the demand for high-grade, intelligent designers became the more pertinent. The final change in the course was therefore made, about a year ago, calling for an entrance examination, for educational work of collegiate grade, and for the extended training in shop work.

Ten draftsman apprentices are finishing their apprenticeship under the less exacting conditions, while 24 are receiving their training in the new course, and their progress augurs well for their future. In fact the training under the prevailing rigid system is expected to prove so effective that the privilege of a one year's post-graduate course in the various testing departments will be extended to all draftsman apprentices whose shop and office work has been very satisfactory and who have a standing of at least 85% in all theoretical studies. These young men will then be eligible for im-

portant positions in engineering or commercial organizations.

TESTER, ERECTOR AND BUSINESS APPRENTICES.—Two other opportunities for systematic training have recently been opened to high-school graduates, one for the preparation of testers and erectors of machinery, the other leading to a business career in a manufacturing establishment. These courses were instituted only within the last few months, and the results can only be foreshadowed.

Tester apprentices must pass an examination the same as draftsman apprentices, and the length of the two courses and the rates of compensation are identical. The practical work consists of about six months of testing motors or transformers, followed by about nine months of assembling and winding, the remaining year and nine months being devoted to a training in the various testing departments for meters and instruments, arc lamps, rectifiers, railway motors, and special electrical machinery, also turbines and turbo-generators. This work will be carefuly supervised by a competent instructor, who will arrange for transfers from one class of work to another, and who will constantly keep the tester apprentices up to the required standard.

Business apprentices are recruited from high-school graduates who have a leaning towards business activity, but not sufficently high scholarship to pass the entrance examination and continue the educational work prescribed for the drafting and testing courses. These apprentices enter upon a two years' course at a compensation of 12 cts. per hour for the first year and 15 cts. for the second year, with a cash bonus of $50 at the successful termination of the course. They begin with six months of general stockkeeping, which acquaints them with the principal materials used in the factory, and leads to an appreciation of the value of these materials. Then follows a nine months' training on the writing of material lists and the compiling of stock reports. In this way the apprentices learn to read drawings and to make up lists of the kinds and amount of materials required for the production of one or several machines or machine parts delineated on drawings. They learn, furthermore, to calculate the losses that result from the cutting off of bars and the punching of various shaped parts. All this leads to accuracy and develops an interest in the value of stock which will show in the stockroom work, of a more independent character, which occupies most of the remaining nine months. These apprentices will also be given a training in shop clerical work, and this will be supplemented by instruction in arithmetic and geometry, the reading of drawings, and simple bookkeeping. This course has been instituted because the great value of proper stock keeping and factory accounting is recognized.

UNIVERSITY STUDENT COURSES.—So far the plans outlined have dealt with methods of increasing the industrial efficiency of workmen and of preparing boys with a grammar or high-school education for the trades and for semi-professional service. The company also seeks to provide, for young men of collegiate engineering training, an entrance into the industrial field which will lead to positions of scientific importance and administrative responsibility.

In common with other manufacturers the General Electric Co. established many years ago, a "student course" providing for a two years' experience in the various testing departments of the works. The young men were usually assigned to a testing department for a certain time, and were then more or less automatically transferred from one department to another until they had covered the whole course within the specified time. They very often did not take the work seriously enough, and in any event their chief aim was to get a general knowledge of as large a field as possible, rather than to acquire thoroughness in each specific field.

The company endeavored to eliminate these defects by organizing some three years ago a supervisory committee. This committee met frequently with the students, and examined each one once or twice a year, in order to test his theoretical and applied technical knowledge, and his alertness for taking full advantage of the educational opportunities offered. In this way the committee was enabled to weed out some who showed no capacity for future responsible work, and to modify the course in each case to fit the individual student, and lead him into the field of his greatest probable usefulness. This arrangement unquestionably improved the general standing of the student training.

The real value of the committee's work, however, has been in the close contact of the members of the committee with several hundred students, and the opportunity to study carefully and specifically the bearing of the student training upon the work of the graduates in various positions inside and outside the factory organization. The committee soon recognized that while the training above described was, in general, a good preparation for those who elect positions in the selling organization, it did not give the right kind of experience to those who are to become designing, manufacturing and administrative engineers. This latter group needs a far more comprehensive knowledge of mechanical processes and a better understanding of the economic forces at work in a modern industrial establishment than can be acquired in the testing departments. With this in mind, the student course was put on a new basis a year and a half ago, and the work so far accomplished bears out the correctness of the premises.

In the present form the student course is divided into two parts, the so-called "engineering" and the "commercial" courses. Admittance to either is dependent on a complete engineering-college education, and almost invariably applicants must appear personally before the committee. The courses last two years and the compensation has been set at 20 cts. per hour ($11 per week) for the first year, 22½ cts. per hour ($12.37) and 25 cts. per hour ($13.75) respectively for the two halves of the second year. Without written agreement it is mutually understood that the student will give to the company two years of faithful service, and that the company, on the other hand, reserves the right to terminate the work of any student who at any time proves that he is not above the average either in capacity and special fitness or in good intentions. Aside from the direct advantage of such a rigid arrangement, is the added result of attracting to the course high-grade young men, some even with one or two years of practical experience after graduation from college, who aspire to positions of prominence and realize the value of a stiff training course with correspondingly good prospects. Even in busy times, when college graduates are in demand everywhere, young men with inherent capabilities will gravitate toward the Lynn course or any other course of equally high order.

Weekly evening lectures have been arranged, which all students are expected to attend, when the engineers and foremen of the company, as well as heads of the business departments, informally address the young men and stimulate a free and frank discussion of the subject under consideration. These lectures cover the principal materials of construction, important manufacturing processes, and the various lines of apparatus manufactured by the company. Occasionally talks dealing with business methods are interspersed. The complete program includes lectures on: (1) Iron foundry practice; (2) Steel foundry practice; (3) Pattern making; (4) Alloys and their properties; (5) Stockroom methods; (6) Forging; (7) Hardening; (8) Welding; (9) Factory cost keeping; (10) Tool steels; (11) Shapes of cutting tools; (12) Cutting speeds and feeds; (13) Piecework rating; (14) Fibrous insulating materials; (15) Oils and varnishes; (16) Porcelain and molded compounds; (17) Shop bookkeeping; (18) Wires and cables; (19) Selection of materials in reference to design; (20) Drawing office methods; (21) Principal machine tools; (22) Care of and repairs to machinery; (23) Interchangeability of parts; (24) The essentials of production; (25) Punch-press operation; (26) Die making; (27) Automatic machine processes; (28) Distribution of labor charges; (29) Requirements of accuracy in machine work; (30) Arc lamps; (31) Incandescent lamps; (32) Mercury lamps and rectifiers; (33) Lighting systems; (34) Factory building construction; (35) Motors; (36) Electrical features of motors; (37) Mechanical features of motors; (38) Motor drive of machine tools; (39) Labor report and pay roll; (40) Fan motors; (41) Industrial motor applications; (42) Railway motors; (43) Gears and pinions; (44) Avoidable factory losses; (45) Meters and instruments; (46) Standardization of instruments; (47) Sheet iron for electrical machinery; (48) Annealing of iron; (49) Transformers; (50) Testing of electrical machinery; (51) Shipping and receiving methods; (52) Steam turbines; (53) Valve gears and governors; (54) Buckets and bucket wheels; (55) Turbo Generators; (56) Turbine testing; (57) Wage payments; (58) Centrifugal compressors; (59) Gas motors; (60) The labor problem; (61) The reading of technical magazines; (62) Salesmanship; (63) Factory management.

Lectures are illustrated, by samples of materials and machines, pictures, drawings and charts. They put the students in possession of up-to-date, practical information which they are not able to get from books or from outside sources. Lecturers and students alike have expressed their enjoyment of these evenings, which inculcate a certain class spirit which results in added ambition, increased loyalty to the employer and a broader conception of the work. This class spirit is discouraged, on the other hand, during the daily work, that the students may never forget that they must earn, as well as learn, in the service of their employer.

Commercial students spend about two months on meter and instrument testing, two and a half months on arc lamp testing and repairing, one and a half months on transformer winding and assembling, four months on transformer and rectifier testing, two and a half months on stationary and railway motor winding and assembling, six months on stationary and railway motor testing, and five and a half months on turbine testing or in other special assignments. They are stimulated to keep in touch with the latest engineering developments by carefully reading the technical magazines, and are shown the value of following up the advertisements in them as one means of getting acquainted with the general features of apparatus manufactured by competitors. Finally, the students are assisted in visiting power stations and installations, where they may see apparatus of various manufacturers and learn to observe keenly the essential points of operation.

Engineering students, on the other hand, receive most of their training in the machine shops, winding departments and drawing office, while the latter part of the course is devoted to testing, or to production, cost or other business activities as the capacity and inclination of the individual student may make advisable. These students are usually started on machine work in the apprentice training room, where they can receive instruction under the most favorable conditions for the first month or two. During this time, also, they can be closely watched, and here the first process of elimination takes place. In the next eight or nine months, students are assigned to various departments of the factory, in some of which they are put entirely on production work, in order that they may come under the influence of the intensity of production and may learn the possibilities of output on various machines, and in others they get experience in tool-making and repairs to machinery. Students who show an inclination toward heavy work are usually assigned to departments in which the machining of turbines, street-car motors, and large motors in general, is done. Students inclined toward light work are, on the other hand, transferred to machine and tool-making departments in the arc lamp, meter and instrument or fan motor building. Some of the students spend a month or two in winding and insulating departments, again with particular reference to their future specialty.

For the following ten months, approximately, students are assigned to the drawing office, where they work first on detail drawings and then on assembly and layout work. Part of this time is devoted to tool designing, when students learn to design a drill jig or milling fixture, or similar auxiliary apparatus for economic wholesale manufacturing. The advantages of the drafting experience are obvious, especially for those who wish to become designing and manufacturing engineers. Inability to read drawings quickly, with an eye that sees the delineations grow into shape and form—an achievement which can usually be gained only through a somewhat extended drafting experience, prevents many college-bred junior engineers from occupying positions of responsibility in designing and manufacturing work. Drawing is the language of the engineer; it is equally useful to the one who supervises draftsmen and designers, or who interprets shop drawings to the mechanic and the foreman, and to the one who wishes to sell a piece of apparatus, when, by means of sketches he can illustrate the advantageous points of manufacture.

The remaining four or six months of the course are devoted to specific work leading to some definite occupation after graduation from the course. Thus, if the committee and the student agree that his future work should lie along manufacturing lines, he may act for a month or two as assistant to a department foreman, and acquire additional specialized shop experience. Another student, better fitted for scientific research or for general mathematical work, may receive a few months' experience on testing, especially of experimental apparatus, and may temporarily be assigned to an engineering department. A student who has shown particular aptitude for commercial work may be given some production and cost-accounting experience, while the future salesman is given an opportunity to spend the remainder of his course in various testing departments. A strong point is made of studying the development of each student, week by week, in order to train him along lines of his greatest capacity.

This purpose, as well as the desire to assist every student in the best way possible and at the same time to exact from him a full measure of service, has led to the appointment of a special instructor whose function it is to keep in almost daily touch with every student throughout the plant. The instructor endeavors to make the foremen of the departments, to whom students are assigned, sympathetic with the whole educational scheme, and to secure for the student work that will be especially helpful to him. He sees to it that every student works at the highest point of efficiency, and whenever he finds him doing his work in anything but the most approved fashion, or using wrongly sharpened tools, or fine feeds where coarse feeds are the proper thing, he explains and insists on remedial action. He, furthermore, tries to inculcate in the student a proper conception of his work, and to make him feel that while he must at all times give service, some one who is sympathetic stands ready to assist him.

The instructor makes a written report of the work of each student once a week, and presents it at the weekly meeting of the committee. The committee discusses every student in the light of the report, lays out his course for four weeks or four months ahead, as the case may permit, and talks personally to those of whom the instructor is not able to report favorably. An admonition is usually considered equivalent to placing the

student on a few weeks' probation, with the understanding that he will be dropped without hesitation if at the end of the probation period a decided improvement cannot be reported. The committee, furthermore, interviews new applicants, and selects those for the engineering or commercial course.

A competent instructor with testing experience will soon be appointed to follow the commercial students through their course unless the commercial course is abandoned on the theory that students with a training such as the engineering course offers will be better salesmen than if they had testing experience alone.

All in all, it would seem that the student training has been laid out on a broad basis, with due regard to the interests of the student as well as those of the company, and it is fair to expect that this training will develop a body of theoretically and practically educated young men, who, on account of their knowledge, their broad conception of things, and their sympathetic outlook, are in line for position of the highest order either with the company or with other concerns.

A definite policy, a sympathetic following up of the students, insistence upon a high standard of work, and a sympathetic oversight of the students by a committee of competent men, are the distinguishing features of the Lynn student courses.

The educational policy of the Lynn Works provides systematic training suitable to all classes of people. The unskilled worker without particular education receives a training adequate to his immediate needs. The grammar-school boy is initiated into the trades on the basis of a four years' course with educational instruction of a high-school character. The high-school graduate is trained for semi-professional service of a technical or business nature, on the basis of a three years' course with educational instruction of collegiate grade. The college graduate is prepared for professional service of the highest order, on the basis of a two years' training of which the educational instruction assumes the character of a post-graduate college course.

Obviously, there are other ways of obtaining these results. Cooperative efforts between the engineering college and the factory, for instance, may be substituted for college instruction, followed by practical training through a student course.* Educationally and economically, the scheme is sound.

More Data as to the Water-Supply for the Panama Canal and the Seepage from Gatun Lake.

The question whether the available water-supply for the Panama Canal is going to be sufficient was brought forward by Mr. Julio F. Sorzano, M. Am. Soc. C. E., in a paper published in the October "Proceedings" of the American Society of Civil Engineers. In our issue of Nov. 11, 1909, we discussed Mr. Sorzano's paper and called attention to a number of features in connection with the water-supply which seem to ensure its sufficiency, notwithstanding the predictions of scarcity made by Mr. Sorzano.

Since the appearance of Mr. Sorzano's paper, full discussions have been presented by Col. H. F. Hodges, M. Am. Soc. C. E., of the Isthmian Canal Commission, and Mr. C. M. Saville, M. Am. Soc. C. E., who is located on the isthmus in direct charge of the investigations relating to water-supply. These discussions give such authoritative data relative to the future water-supply of the canal that some presentation of them in these columns seems worth while, for the benefit of any of our readers who may still be concerned lest errors have been made in the engineers' estimates of water-supply.

We may preface our abstract of Col. Hodges' and Mr. Saville's statements, however, by the remark that to those working on the isthmus during November and December, discussion concerning scarcity of water must have seemed a work of supererogation.

During these months no less than three very heavy floods have occurred. From Nov. 11 to Nov. 27, the Chagres River was at a high flood stage, and it has been estimated that during those 16 days no less than 55,650 million cubic feet of water flowed past Gatun. This represents an average flow during the whole period of 16 days amounting to 37,890 cu. ft. per second, which is equivalent to 28.70 cu. ft. per second per square mile of tributary watershed. Had the Gatun Dam been in place, so that all this water had been retained in Gatun Lake, it would have raised the surface of the lake to 49 ft. above sea-level and would have covered an area of nearly 90 square miles. Put in other words, the flood brought down enough water to about one-third fill Gatun Lake to the normal elevation of 85-ft. above sea-level.

Two other heavy freshets at the close of December, although of comparatively short duration, caused a flood in the Chagres of record-breaking height. This heavy flood was caused by extraordinary rainfalls, the heaviest amount of rainfall for one day ever recorded on the isthmus being attained on Dec. 29 at Porto Bello, when 10.86 ins. fell. The record of total rainfall for one month was also broken at Porto Bello, the December record showing a rainfall of 58.17 ins. at this point. Along the line of the canal, the December rainfall varied from 12.12 ins. at Balboa to 31.48 at Gatun. The elevations reached by the Chagres at Alhajuela and Bohio were greater than any hitherto recorded.

Of course, it will be freely admitted that these heavy flood stages in the Chagres, occurring during the rainy season, do not at all affect the contentions of Mr. Sorzano, which had to do with the sufficiency of the water-supply during the dry season.

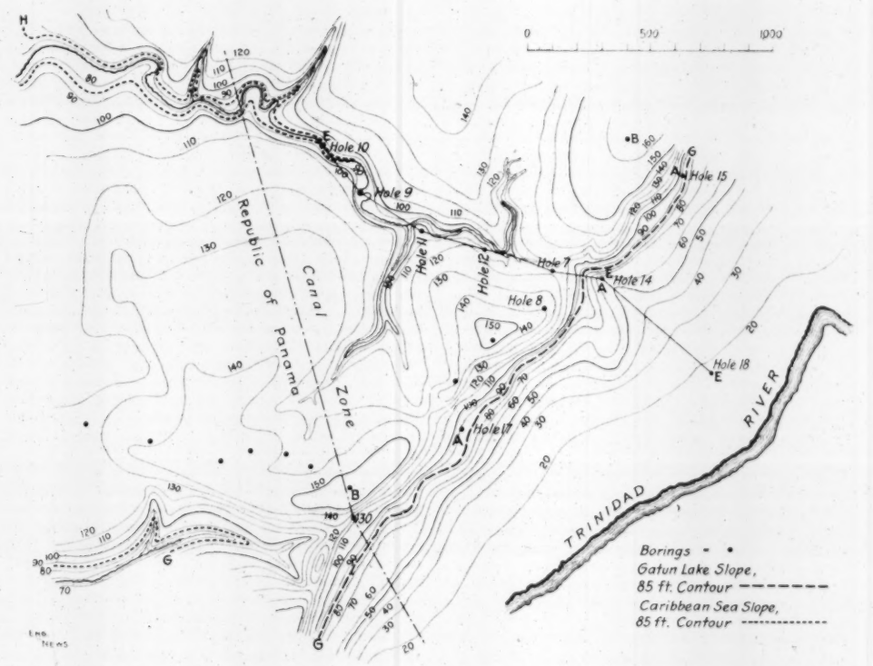


FIG. 1. MAP SHOWING TOPOGRAPHY OF RIDGE AT ESCOVAL BETWEEN GATUN LAKE AND THE OCEAN.

Turning now to Col. Hodges' discussion: It appears, in the first place, that Mr. Sorzano based his computations on a flow into Lake Gatun during the dry season, which, he said, "will rarely average more than 1,200 cu. ft. per second, and this may be considerably less in dry years."

In contrast to this, Col. Hodges states that the minimum daily average rate of flow for the four months of the dry season, in the *worst known* dry season for 19 years, is 1,190 cu. ft. per second. In the average dry season the daily average discharge into Lake Gatun throughout the season is 3,030 cu. ft. per second.

Turning now to Mr. Sorzano's estimates for the losses from the lake during the dry season, Mr. Sorzano first estimated a loss by evaporation from the surface of the lake amounting to about ¼-in. per day. Col. Hodges thinks that this loss will be largely offset by the evaporation which at present takes place from the dense growth of vegetation that now covers the whole area to be overflowed. Thus, Col. Hodges says:

> In debiting the lake with evaporation from its surface, one should not forget to credit it with the unknown amount by which the river flow is now reduced by the vegetation growing over the lake bed.

As for percolation through the bottom and sides of Gatun Lake, which in Mr. Sorzano's computations was assumed to be a source of great loss, Col. Hodges states that the Camacho Reservoir alluded to by Mr. Sorzano as an example of the permeability of the rock on the isthmus, a present supplies from a watershed of about one square mile a total of about 2,000,000 gals. daily aside from all the losses due to evaporation, percolation, "border evaporation," etc. Such a flow over the watershed tributary to Lake Gatun would leave about 4,000 cu. ft. per second available for navigation purposes.

Col. Hodges discusses further the estimates made by Mr. Sorzano for water consumption by the hydro-electric plants, the locks and elsewhere, and finally reaches the conclusion that after allowing at a reasonable rate for all the losses, there will be left in the driest year a total available supply for navigation of 2,745 cu. ft. per second. This would allow 48 complete passages through the canal per day, with a remainder of 623 cu. ft. per second as a margin. Col. Hodges believes this margin to be sufficient to cover any underestimate of the losses, and he feels confident that the water-supply will prove adequate to the needs of the canal for a great many years, if not for all time to come. Should it ever become necessary to increase it, this can be done very simply by the construction of a dam on the Upper Chagres River at Alhajuela or elsewhere, which will permit of increased storage to supply the deficiency during the dry season. The duty of building this dam may be properly left to posterity, should the need ever arise.

This estimate of Col. Hodges is based on the minimum for the driest year ever recorded in 19 years. The daily flow of the average dry season is nearly three times this minimum, so that only once in a score of years is there likely to be any such thing as an approach, even, to the limitations set forth in the preceding paragraph.

In view of the above authoritative statements by Col. Hodges, it would seem that the engineering profession, may feel secure as to the soundness of the plans for the canal water-supply.

There is only one feature of Mr. Sorzano's paper on which some further word seems profitable. We refer to his prognostication as to possible percolation from the lake. This percolation he assumed at nearly ½-in. per day over the entire surface of the lake, which, at the normal water-level, will cover nearly 160 square miles. As we showed in our issue of Nov. 11, Mr. Sorzano based this estimate of percolation on data recording seepage from canal levels, and on the rate of seepage through soils on the isthmus determined

*See address before the American Institute of Electrical Engineers, June 1908, A Method of Training Engineers.

in the course of experiments on materials for the Gatun Dam. What possible relation there could be between such percolations and the leakage from such a lake basin as the Gatun Lake passes our comprehension.

In the discussion on Mr. Sorzano's paper, this fact was pointed out by others. Mr. Grunsky, for instance, stated that figures quoted by Mr. Sorzano for seepage from the Kings River and Fresno Canal in California were determined by Mr. Grunsky himself, and the seepage was but a few feet vertically downward to the water-tube. Mr. Theodore Paschke, in his discussion, showed that the natural wash of the streams flowing into Gatun Lake will eventually cover the whole bottom of the lake with a waterproof blanket of fine silt which would choke up the flow through the fissures in the rock which Mr. Sorzano assumed to exist.

But the question arises, whether there *are* such fissures in the Isthmian rocks. Is there any prospect that Lake Gatun is going to lose its water through leaks in the hills and mountains which surround it, as rapidly as it is accumulated when the outlet is closed by the Gatun Dam?

With all the experience accumulated by the engineering profession in the damming of thousands of river basins in every continent of the world, it seems almost childish to discuss such a question. But there has been so much published in the popular journals regarding the danger that Gatun Lake would not hold water, that it is perhaps worth while to reprint here what Mr. Saville has to say on this subject.

We may remark here that Mr. Saville's discussion is a remarkably complete and convincing statement as to the whole question of the canal water-supply. It will appear in full in a forthcoming volume of "Transactions" of the American Society of Civil Engineers. We reprint below only that part of the discussion referring to the question of percolation. It will be seen that the engineers on the isthmus have not left this matter of percolation to chance and guesswork. Parties under Mr. Saville have been examining the low saddles in the hills which will surround the lake, to see whether percolation through the rock or earth at the narrowest places was anywhere likely to occur. Only at one place was a situation found where the disintegrated rock overlying the bedrock is of a porous character, rendering it desirable to carry a concrete cut-off wall or other impervious structure across the lowest point of the saddle, reaching to a maximum depth of 25 ft. With this exception, the thinnest rock section which will confine the future Lake Gatun is over 400 ft. thick, and the rock is fine-grained and impervious.

We commend Mr. Saville's discussion to the particular study of those of our readers who may have been disquieted by the lugubrious prophecies concerning the alleged earthquake-shattered rocks on the isthmus, and the prospect that the future Lake Gatun would leak like a sieve.

Mr. Sorzano's statement that there is "usually quite a loss of water by percolation through bottom and sides when a deep storage reservoir is formed on natural ground" does not seem to be founded on fact. If this were the case, the storage of water for municipal and commercial uses would be almost prohibitive in its cost. I do not understand that any anxiety is being felt regarding the holding of water in the big Ashokan Reservoir for the New York Supply, which, I think, has not been stripped, nor do I believe that there is any appreciable loss of water from the Croton Reservoir in New York or the Wachusett Reservoir in Massachusetts. This latter reservoir was stripped, but for other purposes than examination of its bottom and sides for percolation. In fact, the very stripping of this reservoir should tend, if anything, to make it more porous, as the fine upper loam and soil is usually a much more effectual seal than are the under strata. The proposition to strip, examine, and make artificially impervious the whole 167 square miles of area to be flooded seems rather extravagant, even when we consider the herculean proportions of the Gatun Dam.

Mr. Sorzano states that the percolation can only be "guessed at." Even so, it has the basis of judgment and experience of engineers who have been studying this particular problem for the past two years, using all standard methods for obtaining results. A "scientific guess," it was aptly termed by one of the Engineer-Commissioners.

The author believes that a margin of safety should be assumed against risks of this kind. It is believed by all who have investigated this problem on the ground, who have actually seen the country, the excavations, and the sample borings, and who are familiar with natural conditions here, that a big margin of safety has been assumed. There is no lack of experimental data, and the methods and results will be referred to later. It is expected to show clearly that the investigations which have been made establish a safe basis for judgment without reverting to general assumptions which may or may not be founded on fact.

Referring to the author's assumption "f": "That joints, seams, and fissures are generally abundant in sandstones, conglomerates, and other rocks like those found in the Canal Zone": This is a comparatively general statement for sandstones and conglomerates, and, were the strata here similar to the coarse sandstones and soft conglomerates of open texture that are found in the United States, the conditions might demand different treatment. But very little coarse sandstone and conglomerate has been found, and that was thoroughly traced by borings and such precautions taken as would prevent danger from this source. This strata itself, however, in its natural condition and with its thick impervious covering of soil would have probably offered no appreciable opportunity for seepage. Almost the entire mass of the rock that has been found in the ridges is called argillaceous sandstone; it is of very

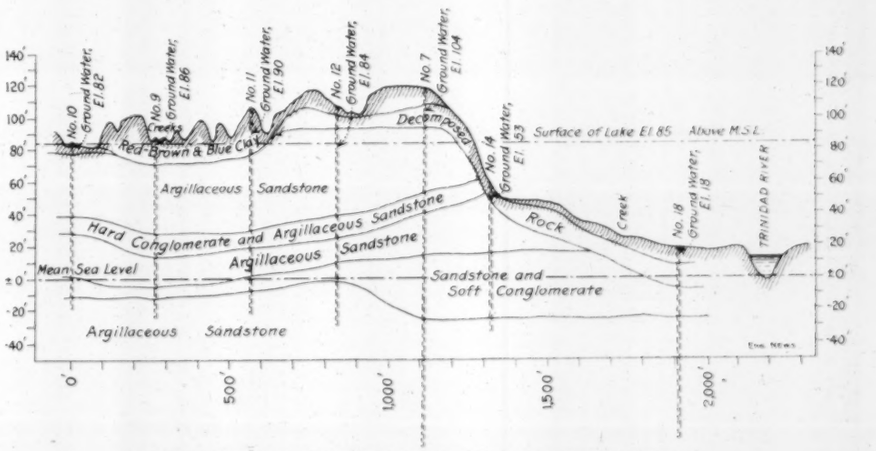


FIG. 2. SECTION THROUGH RIDGE AT ESCOVAL ON LINE E.-E.

finely divided material, and contains very little grit. It is not very hard, is greasy to the touch, and some of it cuts readily with a knife, showing the polished surface of chalk or soapstone. Tests made to determine its porosity showed it to be practically impervious to the flow of water. The seams and fissures in this rock are not abundant, nor do they appear of great extent. Diamond drill cores over 7 ft. long have often been taken from the holes. In no case in all of the borings has any fissure or cavity been found in rock formation unshaken by blasting that could suggest the possibility of a water course or free passage for water that could be considered of serious moment.

The surface soil covering all over the lake area is from 5 ft. to 20 ft. thick on the valley sides, and the bottom layer is several hundred feet thick to the bed rock. This bottom covering extends southerly from Gatun nearly to Bohio, a distance of about 8 miles in a straight line, gradually growing less in thickness and more coarse in texture. It is formed of the clays and very finely-divided materials that have been brought down the river and deposited in the almost stagnant waters which were anciently found below Bohio. This condition appeared both when the region was depressed and the sea extended in, and when it was elevated and a large fresh-water lake was held back by the ridges at Gatun. It also obtains at the present time when the water backs up at Gatun, due to freshets. In any case, the deposit below Bohio is of such a character that it is not probable that this area could be made more impervious by any reasonable artificial methods.

Due to this same cause, the bottom and sides of the proposed lake will become more and more impervious as time goes by and the sedimentary deposits slowly increase. On the sides and crests of the ridges, the rock has gradually weathered to a red clay. This is practically impervious at the surface, but grows more and more open until it reaches the firm and impervious rock. Immediately on top of this rock the material is coarse and open. Here is found the condition for percolation and ground storage of water.

The entire ridge on the west side of Gatun Lake has been meandered for low places in the divide, and from Lagarto to Gatun, where the ridge is lowest, especial investigations have been made, the results of which will be later described. North of Lagarto, the ridges become higher and the rock changes from the argillaceous sandstone to a trap formation.

In the author's assumption "g," it is stated that the absence of lakes and springs in the whole region strongly indicates either good drainage or ample underground communication with water-absorbing strata. As intimated above, no strata has been encountered in any of the borings in the ridges that by a stretch of imagination could be called "water-absorbing" except the layer of disintegrated rock lying immediately on top of the firm formation. If by "good drainage" the author means surface conditions, it can be stated that the topography of this entire basin shows almost perfect conditions, and a study of a relief map will explain the reasons why no mountain lakes appear in this region.

Regarding the absence of permanent springs and surface-water storage conditions, the author is in error. All of the high ridges furnish perennial brooks of greater or less size, due to rainfall conditions, and these are fed by springs rising from the disintegrated rock layer referred to above. Many of these springs take their rise at an elevation far above that of the proposed lake surface, and continue to flow throughout the dry season. Their torrential flow during the wet season has cut their courses deep through the overlying clay covering and down to the firm rock over which they run in a series of rapids and form, in the dry season, a succession of falls and pools. That these streams continue to be fed and to run down the hillsides in periods of little rainfall is evidence of the water-tightness of the rock in the ridges.

On the Caribbean side of the ridge, and extending from Lagarto to Escoval, there is an immense swamp with an elevation of 68 ft. above sea level, and from 50 to 55 ft. above the elevation of the Trinidad River Basin level on the other side of the ridge. There is water in abundance in this swamp throughout the dry season, and borings show that it is in a depression of the rock. If these ridges were permeable to any extent, this swamp would cease to exist, as its waters would seep through into the Trinidad drainage.

The whole Trinidad Basin in the limits of the proposed lake is a series of extensive swamps which are filled with water, and open lagoons with a surface elevation of from 8 to 15 ft. above the waters of the rivers into which their overflow drains through small brooks and cuts in the banks. The Gatun River basin furnishes a similar example of swamp and stream flow. Similar conditions also are found in Lirio Lagoon opposite Culebra and in Rio Grande Reservoir. Quite extensive lagoons are found in the vicinity of Bohio above the ordinary elevation of the Chagres River, and an artificial pond of several acres in extent was formed by an old French dump near the French storehouses on the westerly side of the river. This pond, fed only by comparatively local run-off, has a considerable depth of water in it during the entire dry season, and is utilized as a station for the testing of the current meters that are used in the river gagings. The deep cuttings for the canal have disclosed no water-bearing strata either of rock or gravel, and the bottom of the excavation in many places is far below streams and water-courses that are comparatively near the edge of the cut.

A brief description will now be given of the borings that have been made in the ridges for the particular purpose of investigating the seepage conditions to which the author refers. In running out the ridge line, low saddles were found in the divide at the places called Escoval (el. 118), Arroya (el. 111), Cano (el. 87), and Lagarto (el. 106). Investigations with diamond drill were made, together with comprehensive tests for loss

of water at various elevations. Complete topographical maps were made of the immediate vicinity of the low places, and holes located for drilling where it was thought the worst conditions might be found. Fig. 1 is the topographical map showing the borings at Escoval, and is typical of conditions and methods elsewhere. Fig. 2 shows a section through the ridge at Escoval. The investigations of these ridges show impermeable materials; very little water was lost in any of the bore-holes and only for short and intermittent periods. In all cases where the elevation of the ground permitted, the ground water stands naturally in the holes at elevations higher than the surface of the proposed lake. This condition of ground water is taken as an indication of the imperviousness of the materials forming the ridges.

In the Cano saddle the elevation of the surface and the overlying disintegrated rock is such that a concrete cut-off wall or other impervious structure will probably be necessary to prevent outflow. This will be a comparatively simple affair, reaching only to a maximum depth of 25 ft., and its length will be comparatively short.

At all other places the ridge is of sufficient height and thickness to safely confine the lake. The thinnest rock section, except as noted above for artificial protection, is over 400 ft. and through a fine-grained impervious stratum. The maximum depth explored was about 100 ft. below sea level, and most of the holes were driven to from 10 to 40 ft. below this datum. The surface conditions were carefully noted, and, although exposed on the sides and beds of the streams to the torrential rushes of large quantities of water, the erosion is very little, which is excellent evidence of the permanency and resistance of this formation.

The following statements summarize the methods of procedure that have been undertaken to obtain information on which to base judgment as to the character of the materials in the bottom and side ridges of the basin which is to hold the proposed Gatun Lake. The bottom deposits were thoroughly examined, and the results and conclusions given in the Report of the Isthmian Canal Commission, Appendix E, 1908. A final report on the borings in the Escoval Saddle is to be found in the Report of the Isthmian Canal Commission for 1909 (p. 201). The work at the other saddles—Arroya, Cano, and Lagarto—has been completed since submitting the annual report. Summaries of these reports are given above.

Directions were given by the Chief Engineer to examine thoroughly the ridges on the westerly side of Gatun Lake, both for loss of water by seepage and to develop what construction, if any, would be necessary in the low portions of the ridges. The ridge line southerly from Gatun was run out by a survey party. Following this, all places in the ridge were carefully explored which were either at a less elevation than 150 ft. above mean sea level or had a thickness of less than 2,000 ft. At least two independent parties carefully investigated these places, paying especial attention to stream flow, rock outcrops, and general topography. From this study the lowest and thinnest places were chosen and detailed topography taken, and positions for diamond drill holes were located from the plans. These holes were drilled with particular care to get information regarding their entire depth, and especial precautions were taken and tests made to ascertain the action of water on the formation. From personal investigation on the ground, and knowledge from the seepage tests and study of the samples, I believe that the materials as found in the ridges at Escoval, Arroya, Cano and Lagarto are representative of the formation in the ridges about Gatun and north thereof to the trap-rock region near the southwesterly end of the proposed Gatun Lake.

On the south and east borders of the lake no losses by percolation can be apprehended on account of the height and thickness of the ridges. On the northwesterly side, for a distance of about nine miles from Gatun, the ridges have not yet received the careful attention given south of this point. Some exploration and investigation has been made here, however, and nothing has been found that would cause apprehension. It is believed that the investigations which have been made are more thorough than is usual even with government work, but were justified by the importance of this undertaking.

From these investigations nothing has as yet developed that would suggest increasing the figures for seepage used by the Consulting Board of Engineers. The loss of water by seepage, however, has not been "authoritatively dismissed as 'an impossibility'" as is stated by the author, either by the Board of Consulting Engineers or in subsequent calculations, for on p. 75 and p. 195 of the Report of the Consulting Engineers an amount equivalent to 77 cu. ft. per sec. is cited, and it is my impression that 85 cu. ft. per sec. is the figure now used in calculations.

To sum up, evidence of the impermeability of these ridges is drawn from the following:

(a) The small amount of wash water lost and the ease with which it was regained during drilling.

(b) The fact that the holes could be filled with water, and kept filled to the surface of the ground, and that the only loss at all appeared in the disintegrated layer overlying the rock, which in all cases, except at Cano mentioned above, is at an elevation higher than the proposed lake surface.

(c) That the bore holes to a depth of from 100 to 120 ft., were easily bailed out with the sand pump.

(d) That water did not appear on the face of the ridges during pumping and filling the holes, although this exposed portion was at times less than 150 ft. away.

(e) That water appeared only slightly in one case in a neighboring hole when one hole was being filled.

(f) That when bailing ceased and the holes were clear, the water gradually rose to a higher elevation in the holes than the proposed lake level, due probably to downflow from the disintegrated rock layer above, and remained in this position.

(g) That the exploration has been thorough and to reasonable depths, and that comparatively compact and dense rock has been penetrated.

(h) That streams continuous throughout the dry season are of common occurrence, coming down from the tops of the ridges and fed by perennial springs.

(i) That extensive swamps, lagoons, and ponds are frequent at high and low elevations, and in positions to readily drain if the formation permitted. That the swamps do not dry up during the dry season, but are continually filled with water.

Finally, I desire to quote the opinion of Gen. H. L. Abbot, M. Am. Soc. C. E., (p. 164, Problems of the Panama Canal) who, more than any other engineer, has studied the hydraulic conditions that relate to the Isthmian Canal, and is able to speak with the authority of intimate knowledge. What he has said regarding the conditions above Bohio applies with even more force to the region below that point.

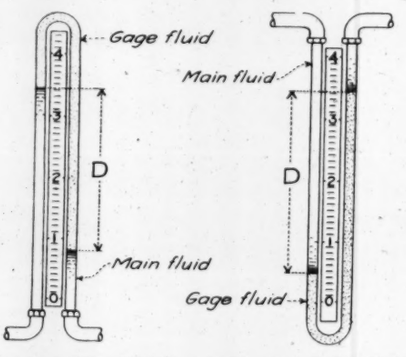


Fig. 1. Gage Fluid Lighter Than Main Fluid.

Fig. 2. Gage Fluid Heavier Than Main Fluid.

Figs. 1 and 2. Two Forms of Fluid Differential Gage.

In the case of the Chagres Valley, the geological examinations give every promise that the water impounded would be retained with even less infiltration than usual; but following their habit of neglecting nothing which could throw light upon the problem, the Engineers of the New Company instituted what is perhaps the most elaborate study of the ratio between downfall and drainage that has yet been made in a tropical valley like that of the Chagres above Bohio. The results leave no doubt that the subsoil is fully saturated with water, and that no open route exists for any considerable subterranean escape. On the contrary, the stream receives large contributions from this source.

In round numbers it appears that of the entire rainfall in the basin about one-third evaporates, another third flows off directly by the bed of the river, and the residue, after a retardation of perhaps three months by its passage through the soil, ultimately reaches the river as ground water. During the dry months it supplies much the larger part of the flow. In fine, the conditions of this tropical basin, as compared with those existing in the northeastern portion of the United States, indicate per square mile about 2.5 times the rainfall, 3.3 times the outflow, and 1.5 times the evaporation.

THE SUPERIORITY OF ENGLISH BRIDGES.—Not long ago an inquiry was carried out and data collected to determine the condition of a number of railway and road bridges constructed of iron, steel and timber in the United States. The results were unsatisfactory, and in some respects alarming. Work had been passed which ought not to have been passed. Neglect had done its worst. Care had been insufficient; and above and beyond all came the direct evidence that designs had been adopted which simply courted decay.

In this country [England] years have passed since a bridge gave way causing loss of life. This is the more satisfactory in that great numbers of our smaller bridges were never intended to carry the loads which are now put on them every day. They are standing proof of the value of a high factor of safety. It may be added that with regard to workmanship and material, British bridges appear, taken as a whole, to be the best in the world. ["The Engineer," of London, England, Feb. 4, 1910.]

Notes on Some Errors of Fluid Differential Gages.

By GEO. JACOB DAVIS, JR.,* Assoc. M. Am. Soc. C. E.

In hydraulic work it is often necessary to measure the difference of the heads existing in a flow at two points. For this purpose gages composed of a suitable arrangement of glass tubes containing fluids of different specific gravities have been devised, and are found very convenient and satisfactory. Most text-books on hydraulics contain descriptions of one or two types of such gages with an explanation of the principle on which their design is based, but mention is never made of the fact that the indications of such gages are liable to comparatively large errors. A few explanatory notes concerning fluid differential gages and the cause and effect of the more common errors to which they are liable are given below.

DEFINITIONS.—All gages based on the principle of using the difference in pressure caused by two columns of equal length of fluids of different specific gravities to balance and measure the difference of head at two or more points are here grouped under the general designation of *fluid differential gages.*

Of the two fluids used, one is entirely contained in the gage and may therefore conveniently be termed the *gage fluid.* The other fluid fills that part of the gage not filled by the gage fluid and also the pressure tubes connecting the gage to the main bodies of fluid whose pressure differences are desired. This second fluid ordinarily is part of the main body of fluid and identical with it, and for this reason is here designated as the *main fluid.* This term is also suggested by the fact that the points where the pressure differences are to be measured are, in a large number of instances, located in water and gas conduits commonly called mains.

The indications of fluid differential gages never correctly represent the true difference of head, and it is therefore necessary to reduce the gage readings to the true head by the use of a factor which depends upon the relative specific gravities of the two fluids involved. This factor is here called the *gage coefficient* of the combination of fluids, and it is here represented by the symbol c. The reciprocal of the gage coefficient is the number expressing the degree of magnification of the difference of head.

THEORY.—The principle on which the designs of fluid differential gages are based may be seen by referring to the sketches Figs. 1 and 2, in which it may be noted that above any horizontal plane, as for instance the zero of the gage scale, the two columns balance, up to the lower dividing surface of the two fluids. From there up to the upper dividing surface the two columns do not balance, having different specific gravities. Above this elevation the columns again balance. The difference of head, is, therefore, balanced by the difference in the intensities of pressure exerted by the two columns of different fluids of length D. If the points between which the difference of heads is to be measured are not in the same horizontal plane a correction due to the difference of elevation of the points must be made to the differences indicated by the gage.

An algebraic statement of the relation existing between the various quantities involved may be deduced by letting

n = the specific gravity of the main fluid,
s = the specific gravity of the gage fluid,
h = the actual difference of head in terms of fluid of specific gravity 1.0,
D = the observed difference of elevation of the fluid surfaces in the gage.

Then for a gage like that shown in Fig. 1,

$$h = n\,D - s\,D,$$

or,

$$h = (n - s)\,D = c\,D \qquad (1)$$

It may be seen from eq. (1) that as long as the specific gravity of the gage fluid (s) is less than that of the main fluid (n) the indications of the gage will be greater than the true difference

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of head. As the value of s approaches n, the value of the gage coefficient decreases, until when s exceeds n the equation does not hold, as the heavier fluid could not be kept in the upper part of the tube. The type of gage shown in Fig. 2 must then be adopted. For this type of gage the equation is

$$h = s\,D - n\,D,$$

or,

$$h = (s - n)\,D = c\,D \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

From this equation it may be seen that under such conditions the value of c increases continuously as s increases, but that for values of s less than $n + 1$ the gage will magnify the difference of head, while for values greater than $n + 1$ it will reduce the apparent difference of head. The values of the gage coefficient, c, and its reciprocal, the degree of magnification, for various values of s have been plotted in Fig. 3, using unity for the value of n.

Fluid differential gages have been used for many years, but until recently the only gage fluids used were mercury and air. Mercury when used as the gage fluid with water reduces the true difference of head to an apparent difference 1/12.6 as great, while air used with water causes a very slight magnification of the true head. Flad was probably the first to use a gage fluid the density of which approximated that of the main fluid. In 1885, he used oil having a specific gravity less than unity to measure the difference of head of water. Cole, in 1897, made further progress in the development of this type of gage by using mixtures of fluids so proportioned as to furnish the specific gravity and hence the multiplication desired in the gage, and he also made use of coloring matter in the gage fluid. Without knowledge of Flad's and Cole's work Williams used various oils in fluid differential gages in 1898, and made the first reported attempts to calibrate such gages.

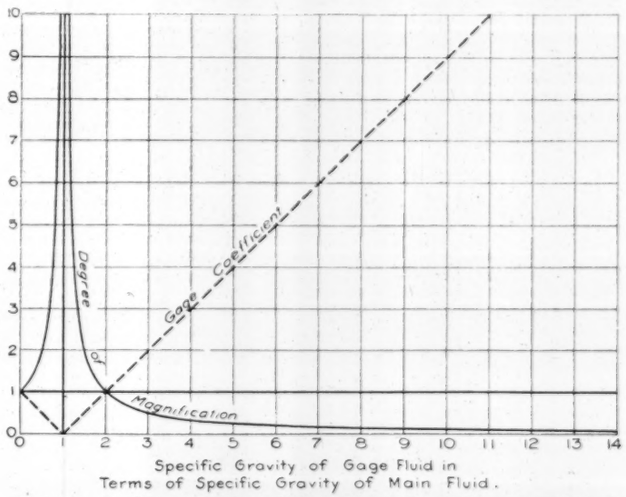


FIG. 3. VARIATION OF GAGE COEFFICIENT AND MAGNIFICATION WITH VARYING RATIO OF SPECIFIC GRAVITIES OF THE TWO FLUIDS.

Practical Considerations.

ERROR IN SPECIFIC GRAVITY.—The specific gravities of fluids vary in accordance with their conditions of purity, pressure and temperature. For most fluids suitable for use in gages the variations are of sufficient magnitude to cause appreciable changes in the gage coefficient. The effect on the gage coefficient of an error in the determination of the specific gravity of one of the fluids, or of a change in the specific gravity due to temperature or pressure changes or impurities in the fluids, is greater when the densities of the fluids are nearly the same than when they are quite different. This fact is made apparent in Fig. 3. Not only the total error is greater but the percentage of error in the coefficient also is greater in gages giving a large magnification. Table I has been prepared to illustrate this point, by making the assumption that an error of one unit in the third decimal place has been made in the specific gravity of either the main fluid or the gage fluid (positive for the former and negative for the latter). If an error of one unit in the third decimal place is made in the specific gravity of each fluid the error in the gage coefficient will be twice as large as the values tabulated.

TABLE I.—PERCENTAGE ERROR IN GAGE COEFFICIENT WHEN SPECIFIC GRAVITY OF EITHER FLUID IS ONE UNIT OUT IN THIRD DECIMAL PLACE.

Specific gravity of main fluid. n	Specific gravity of gage fluid. s	Gage coefficient. c	Error in gage coefficient.
1.0	0.5	0.5	0.20%
1.0	0.6	0.4	0.25%
1.0	0.7	0.3	0.333%
1.0	0.8	0.2	0.50%
1.0	0.9	0.1	1.00%
1.0	0.95	0.05	2.00%

In this table it is shown that the percentage of error in the gage coefficient due to the assumed error in one of the fluids rapidly increases as the gage coefficient decreases; reaching 2% when the fluids have such densities as to give a magnification of 20 times the true head.

EFFECT OF IMPURITIES.—The densities of river waters as a rule differ only slightly from that of pure water, yet even among this class will be found a large number whose densities differ enough to cause appreciable errors if the specific gravity is assumed to be the same as for pure water. As examples may be cited the Schuylkill River, at Philadelphia, specific gravity 1.00068; Thames at Wickenham, England, specific gravity 1.0003; Hot River, Yellowstone Park, specific gravity 1.00157. Spring and well waters generally contain more dissolved solids than do river waters and hence have higher specific gravities. Oceans and salt lakes have very much higher specific gravities, running from 1.0275 in the Gulf of Mexico to 1.172 in the Dead Sea. The main fluid may, therefore, be considered always open to suspicion as to variations in its specific gravity due to impurities.

Likewise commercial liquids suitable for use as gage fluids have quite variable densities because of the fact that they are often adulterated or that they are, like kerosene, mixtures of various chemicals the proportions of which are likely to vary somewhat in different samples. For accurate work with fluid differential gages the gage coefficient should be known to the third decimal place in ordinary cases and to the fourth place when the multiplication of the difference of head is 20 times or more.

EFFECT OF PRESSURE CHANGES.—The error due to neglecting the effect of variations in pressure may be illustrated by considering a couple of practical cases.

In the first case air will be used as the gage fluid and water as the main fluid. The density of air at atmospheric pressure is 0.0807 lbs. per cu. ft., which makes its specific gravity referred to water equal to 0.001293. At constant temperature its specific gravity varies inversely as the pressure. The specific gravity of water is 0.99974 at atmospheric pressure, and at 10° C. At this temperature the compression of water is 0.000047 per unit volume per atmosphere, hence its specific gravity at 10° C. under any pressure of p atmospheres is

$$\frac{0.99974}{1 - 0.000047\,p}$$

For these conditions the values of the gage coefficient at different pressures have been computed by eq. (1) and are given in Table II.

TABLE II.—VARIATION OF GAGE COEFFICIENT WITH PRESSURE FOR WATER-AND-AIR GAGE.

Pressure in lbs. per sq in.	Specific gravities at 10° C. Water.	Air.	Gage coefficient. c	Per cent. error.
14.7	0.9997	0.0013	0.9984	0.16%
58.8	0.9999	0.0052	0.9947	0.53%
147.0	1.0002	0.0130	0.9872	1.28%
294.0	1.0007	0.0260	0.9747	2.53%

In practical work it has been customary to assume that the difference D indicated on the air gage is equal to the true difference of head, or, in other words, that the gage coefficient is unity. The errors due to such an assumption have been computed by deducting the true values of c, as given in column 4, from unity, and they are given in the last column of Table II.

It may be seen that when the gage is working under atmospheric pressure, with air as the gage fluid, the error of neglecting the weight of the air is only about 1/6 of 1%, but when the gage is working under high pressures the error occasioned by neglecting the variation in the specific gravities becomes quite appreciable, amounting to as much as 2½% when the pressure is less than 300 lbs. per sq. in.

Such large errors are not to be expected when liquids are used as gage fluids because of the slight compressibility of liquids. However, as pointed out above, slight variations in specific gravity cause greater varations in the value of the gage coefficient when the specific gravities of the two fluids are nearly alike than when they are very dissimilar. The actual magnitude of the errors due to this cause when a liquid is used as gage fluid will be illustrated by the use of toluene and water as gage fluid and main fluid respectively. The specific gravity of the former liquid is 0.86600 at a temperature of 10° C., and its compression is 0.000079 per unit volume per atmosphere. Computing by eq. (1) as in the case with air as gage fluid, the gage coefficient for toluene and water is found to be $c = 0.13376$ at atmospheric pressure, $c = 0.13353$ at 10 atmospheres (147 lbs. per sq. in.), and $c = 0.13231$ at 20 atmospheres (294 lbs. per sq. in.). If, as has been the custom in the past, the gage coefficient is assumed to be constant at $c = 0.13376$ independently of variations in pressure, the error introduced into the computations of difference of head will be about 0.17 of 1% at 147 lbs. pressure, and 1.09% at 294 lbs. per sq. in.

In hydraulic work pressures often exceed those here considered, so the errors shown are not outside the realm of practice. Some other liquids suitable for use as gage fluids have higher rates of compression than has toluene and would therefore occasion larger errors if the specific gravity is the same. With higher specific gravity and higher rate of compression the error would be considerably augmented. It is necessary, therefore, in selecting a new gage fluid to investigate this matter to see if the error due to compression is important at the pressures at which the gage will be used.

EFFECT OF VARIATIONS IN TEMPERATURE.—The magnitude of the error due to neglecting the effect of temperature changes will be illustrated by the use of kerosene and water as the gage fluids. The specific gravities of pure water and of a sample of kerosene at various temperatures and constant pressure have been arranged in Table III., and from them the values of the gage coefficient have been computed by eq (1) as was done for Table II.

From this table it may be seen that a variation of 10° in the gage temperature will cause about 5% variation in the gage coefficient. Hence large errors may be introduced into the computed value of the difference of head if the specific gravities at an average temperature be used.

TABLE III.—VARIATION OF GAGE COEFFICIENT WITH TEMPERATURE; KEROSENE AND WATER GAGE.

Temperature of gage fluids, Degr. C.	Specific gravities— Water.	Kerosene.	Gage coefficient. c
4	1.0000	0.8265	0.1735
10	0.9997	0.8190	0.1807
20	0.9982	0.8069	0.1913
30	0.9957	0.7947	0.2010

EFFECT OF VISCOSITY.—In small tubes a viscous fluid, especially one which adheres to the walls of the tube, will lag. The error due to this cause will reverse its sign when the increment of pressure changes sign. On this account it is a very uncertain quantity and its effect should be avoided by selecting fluids of low viscosity.

EFFECT OF CHANGES IN CAPILLARITY.—Capillarity is a phenomenon of surface tension, and arises from the attraction or repulsion that exists between the particles of a liquid surface and a solid. The amount of such attraction or repulsion between the same liquid and solid depends on the condition of the surfaces of the solid and of the liquid and on the gas that is present, if there be any. In ordinary barometric tubes it has been observed that as the surfaces of mercury and glass change their condition with time and exposure to the atmosphere, a steady change in the capillary effect is usually observed, ordinarily producing a steady rise in the barometric reading. The amount of this effect has been studied in the case of mercury and glass, but data are not available as to the magnitude of this effect in the case of the lighter fluids such as are used in multiplying gages. The effect has, however, been noticed, and has been quite troublesome with some fluids.

If the change in the condition of the surfaces were uniform the effect would cancel in a differential gage; but the change is not uniform. In certain places along the bore of the tube such a change takes place on one or more sides of the tube as to change the capillary effect from an attraction to a repulsion, the result being that the meniscus is distorted and raised or lowered from its correct position. Heads measured when the meniscus is rising differ from those measured when the meniscus is falling, due to changes in the shape of the meniscus. To safeguard against trouble from these causes a combination of fluids having as flat a meniscus as possible should be used and the glass tubes should be thoroughly cleaned.

CONCLUSIONS.—The errors likely to occur in the use of fluid differential gages due to certain causes have been pointed out singly, but it must be borne in mind that all of the errors discussed may and usually do occur simultaneously and that the errors may at times all have the same sign, resulting in a large total error. Inasmuch as the errors increase rapidly with the degree of magnification it would be prudent, in the present state of our knowledge of gage fluids, to select those giving only a moderate magnification, perhaps setting 0.1 as the minimum limit of the gage coefficient. On account of the various disturbing elements already discussed the gage coefficient should not be computed from the specific gravities of the fluids, but should in all cases be determined experimentally by putting samples of the fluids in the gage in which they are to be used finally and comparing the differences indicated on this gage with the actual head indicated on a water gage subjected to the same pressure and temperature.

Operating Costs of U. S. Seagoing Dredges.

A record of the performances of U. S. seagoing dredges for the past year, published in tabular form in the annual report of the Chief of Engineers, U. S. Army, shows the amount of material handled by each dredge, the coal consumption and the operating cost.

The 24 dredges included in the Chief Engineer's report vary widely in size and equipment. The smallest vessel, the "Winyah Bay," has a displacement of 466 tons, while the largest, the "Chinook," is of 5,590 tons displacement. In the condensed table presented herewith, the "Chinook" is not included, for the reason that she is reported only as being "now out of commission," and no data of her performance is given. The pumping equipment varies from two 10-in. to two 20-in. centrifugal pumps, and some of them are at a considerable disadvantage on account of their antiquity. The "Gedney," built in 1887, is at a still further disadvantage owing to slow dumping apparatus. To dump one of the "Gedney's" average loads of 572 cu. yds. takes 34 minutes, whereas the "Manhattan," with modern equipment, can dump her load of over 2,000 cu. yds. in less than ten minutes.

The average depth of dredging varied from 15 or 20 ft. to 30 or 35 ft. The maximum working depths occurred in the passes of the Mississippi River and in Ambrose Channel, New York Harbor. The speed while dredging is necessarily low for all vessels and varies from ½ to 4 knots. The unloaded speeds range from 7 to 11 knots.

In the dredging of harbors at New York, Mobile and Galveston, in the Delaware River and on Lake Michigan, about 300 or 400 hours were lost by each dredge during the year on account of bad weather. Elsewhere the loss from this cause was less than 80 hours and in several cases it was not over 25 hours. The dredges at work on the Great Lakes were obliged to remain in winter quarters from two to four months, but this time is not included in the bad-weather loss.

The material pumped per hour varies considerably for dredges with equivalent pumping equipment. The "Sabine," working with two 10-in. pumps in "soft blue mud" at Sabine Pass, Tex., pumped 459 cu. yds. per hour, while the average rate for one 15-in. or two 10-in. pumps was only about 300 cu. yds. The performance of the "Burton" with two 15-in. pumps was surprisingly poor, only 264 cu. yds. per hour as compared with the average for corresponding equipment of about 500 cu. yds. The maximum rate of pumping was maintained by the "Raritan" (Ambrose Channel) with two 20-in. pumps and was 995 cu. yds. per hour. In general, the most easily handled material seems to have been found along the northern shore of the Gulf of Mexico, while that in the passes of the Mississippi River in Louisiana was uniformly bad.

The costs given in the table cover only the operating expenses, such as wages, fuel, repairs, etc. They include no allowance for office expenses, interest or depreciation. The highest cost per cubic yard of material removed was 22.4 cts., and occurred in the case of the "Gedney," which had also the highest coal consumption. The "Gedney's" poor showing is doubtless due in part to the length of time required to dump her as well as to the distance which she had to travel (nine miles) to point of dump. The "Gedney" is much smaller than any other dredge operated with anywhere near so great a distance to dump. The "Burton," with 1,200 tons displacement and 6.4 miles to dump, most nearly approaches the "Gedney's" conditions and is a close second in coal consumption, but her high consumption is probably due to some extent to her poor pumping performance already referred to. The best results were attained by the large modern dredges working in Ambrose Channel, New York Harbor, where, in spite of the relatively long distance to dump, the cost was kept down to about 4 cts. per cubic yard.

A particularly noteworthy record is that of the "Gen. C. B. Comstock" in Galveston Harbor. The operating cost for this dredge, with comparatively small displacement and only fairly good pumping performance, was 3.9 cts. Oil was used for fuel and the consumption, 0.53 gals. per cu. yd. of dredged material, was remarkably low.

RECORD OF PERFORMANCE OF U. S. SEAGOING DREDGES FOR THE YEAR ENDING JUNE 30, 1909.*

Name of Dredge.	When Built.	Tons Displacement.	Number and Size of Pumps.	Location or Dredging.	Character of Dredged Material.	Material (cu. yds.) Pumped per Hour.	Total Number of Loads.	Total Amount (cu. yds.) Dredged.	Average Distance to Dump, miles.	Pounds Coal Consumed per cu. yd. Material Dredged.	Cost per cu. yd., Inc. all Repairs.	Remarks.
Gedney	1887	751	Two 15"	Main ship channel, New York Harbor.	Sticky mud, sand.	319	121	69,241	9	24.4	$0.224	Worked 5 mo.; transferred.
Charleston	1891	517	One 18"	Mobile outer bar, Alabama.	Sand and mud.	346	549	149,309	¾	11.1	0.181	Laid up 6 mo.; lack funds.
W. S. Ladd	1893	750	Two 15"	Harbor bars, Portland, Ore.	Sand.	467	852	341,430	1	6.9	0.065	Worked 9 mo.
Cape Fear	1895	...	Two 10"	Cape Fear River, N. C.	Sand and mud.	237	1,575	460,519	4	9.7	0.052	.....
Gen. C. B. Comstock	1895	704	Two 15"	Galveston Harbor, Tex.	Sand, clay, shell and silt.	457	2,883	1,860,620	1½	0.53†	0.039	.....
Winyah Bay	1898	466	One 15"	Winyah Bay and Charleston Harbor, S. C.	Soft mud, sand & coral rock	289	943	260,200	2.66	6.27	0.072	Repairing 1 mo.; laid up 3½ mo.
Benyaurd	1900	2,006	Two 20"	Passes of the Mississippi River, La.	Sand, mud and silt.	588	922	1,718,549	2	8.25	0.063	Repairing 2 mo.
Sabine	1901	600	Two 10"	Sabine Pass, Tex.	Soft blue mud.	459	1,955	381,225	1.15	0.7†	0.068	Repairing 1 mo.; laid up 1 mo.
Cumberland	1902	1,451	Two 18"	Savannah Harbor, Ga.	Sand, mud, clay & gravel.	670	854	761,761	2.3	8.55	0.115	Repairing 2 mo.
Gen. Gillespie	1904	1,200	Two 15"	Harbors, Lake Michigan.	Sand and shell.	516	935	524,126	1	13.9	0.088	In winter quarters 2 mo.
Manhattan	1904	3,200	Two 20"	Ambrose Channel, New York Harbor.	Sand, gravel and mud.	862	1,208	2,498,457	7	9.67	0.040	.....
Atlantic	1904	2,674	Two 20"	Ambrose Channel, New York Harbor.	Sand, mud, gravel & stone.	879	1,275	2,667,321	6	9.3	0.038	.....
Key West	1904	498	One 15"	Tampa Bay and St. Johns River, Fla.	Sand and broken shells.	285	1,344	438,748	0.61	10.4	0.091	.....
Savannah	1904	1,236	Two 15"	Harbor bars, Savannah, Ga.	Sand, clay and mud.	572	1,028	807,236	3	8.36	0.070	Laid up 1 mo. overhauling.
Sumter	1904	1,650	Two 18"	Passes of the Mississippi River, La.	Sand, clay and mud.	366	342	288,852	3½	14.25	0.105	Worked 6 mo.
Burton	1905	1,200	Two 15"	Harbors, Toledo and Sandusky, Ohio.	Sand and mud.	264	330	227,109	6.4	21.4	0.110	Winter quarters 4 mo.
Caucus	1905	1,650	Two 18"	Carrabelle and Pensacola Harbors, Fla.	Sand.	678	556	502,428	2	12.1	0.078	.....
Delaware	1905	2,750	Two 20"	Delaware River, Del.	Sand, mud, gravel, clay & broken stone.	871	647	2,050,222	6	8.8	0.041	Repairing 2½ mo.
St. Johns	1905	1,047	Two 18"	Passes of the Mississippi River, La.	Sand, mud and clay.	497	1,059	670,584	1	13.3	0.110	Repairing 1 mo.
Navesink	1908	2,929	Two 20"	Ambrose Channel, New York Harbor.	Sand, gravel, mud.	876	1,042	2,636,123	7½	9.1	0.041	.....
Raritan	1908	2,929	Two 20"	Ambrose Channel, New York Harbor.	Sand, stones, mud, debris.	995	1,125	3,002,537	7½	8.1	0.039	.....
Clatsop	1908	1,100	Two 18"	Delaware River, Del., and Portland, Ore.	Sand, mud and clay.	386	115	97,404	...	...	0.144	Put in commission this year; 2 mo. trials; 5 days regular operation.
Galveston	1908	3,500	Two 20"	Galveston Harbor, Tex.	Sand, mud and clay.	707	623	1,272,659	1	0.92†	0.059	Put in commission this year; operated 7 mo.

*Condensed from a table in the annual report of the Chief of Engineers, U. S. Army.
†Gallons of fuel oil.
‡Dimensions given are suction pipe diameters.

Designs For Hydraulic Power Plants Subject To Reduced Head During High Water.

In the development of water power on large rivers, where the available head is small, it often happens that the capacity of the plant is greatly reduced at flood stages of the river by the loss of head. At present the only way of maintaining the output from such a station at flood stages is to provide surplus turbines and generators; but this of course adds largely to the investment and the plant thus installed is used only a few days during the year.

To meet such conditions, Mr. Clemens Herschel, M. Am. Soc. C. E., devised in 1898 a "fall increaser,"* a comparatively inexpensive apparatus, with no moving parts, which utilizes the energy of the freshet water to produce a suction head in the draft tubes from the turbines, thus compensating for the increased height of tail water. The device is a development of Mr. Herschel's well-known Venturi tube water meter.

Recently, Mr. Herschel has prepared comparative plans and estimates for a low-head water-power installation, using in one case his "fall increasers" and in the other a special equipment of turbines and generators for use during high water. The plant in question is designed to develop 2,400 KW. and the ordinary head is 13 ft. It has been possible, by the application of eight of these fall increasers, to save two complete generating outfits, with a decrease of 15% in the length of the power-house, and a total financial saving of from $25,000 to $50,000, according to the exact arrangement adopted. This case is shown in the accompanying figures. At low-water seasons, the upstream level is 130 ft. above datum and the tail-water level is at 115 ft. At freshet time the upstream water stands at 138 ft. and the tail-water at 135. Fig. 1 shows, in cross-section, the original design of the power plant. In one of the alternative designs made by Mr. Herschel, shown in Fig. 2, it is proposed to place horizontal turbines so that their draft outlet is only slightly above the 115-ft. level, in order to use the low-water heads as simply as possible. As in this plant the tail water is above the 115-ft. level on most days of the year, the main floor of the station is below the tail-water level much of the time.

To meet such objections, an alternative scheme, shown in section by Fig. 3, was arranged with the turbines raised so that the draft outlets were at about the 130-ft. level. Therefore it was necessary to make the intake as a siphon. In this design, as in the alternative one, the fall increaser is placed just below the 115-ft. level, so as to be wholly submerged at all times. To start the turbines and to keep the wheel cases clear of air a small fall increaser, say of 6 ins. diameter, is operated as an air ejector.

The following tabulation shows a summary of the comparative estimates. Plan I. requires two hydraulic turbines to compensate for back water. Plans II. and III. substitute Herschel fall increasers, Plan II. being the first alternative mentioned above.

	Plan I.	Plan II.	Plan III.
Power-house	$60,000	$91,000	$96,000
Turbines and dynamos	86,500	59,000	79,000
Back water turbines and dynamos	54,000	.....	.....
Total	$200,500	$150,000	$175,000

*Described in Engineering News, 1908, Vol. Jan.-June, pp. 635 and 673.

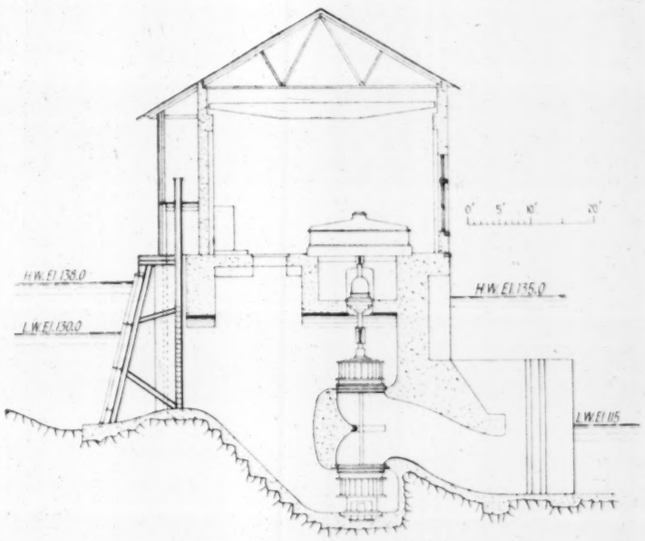


FIG. 1. CROSS SECTION OF A 2,400-KW. HYDROELECTRIC PLANT, ORIGINAL DESIGN.

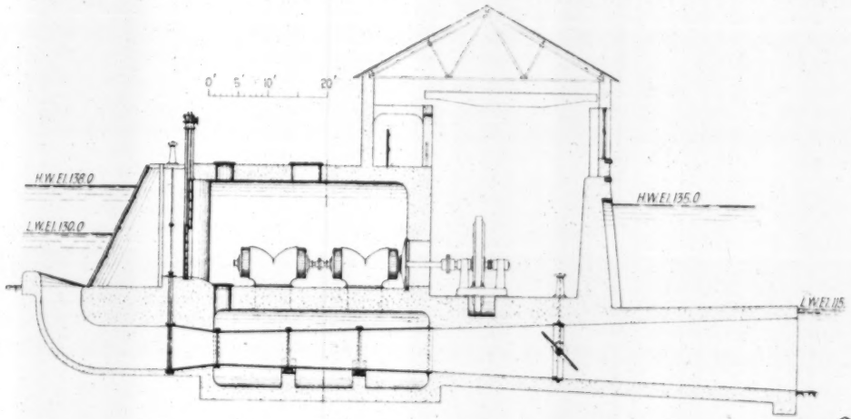


Fig. 2. Arrangement II.

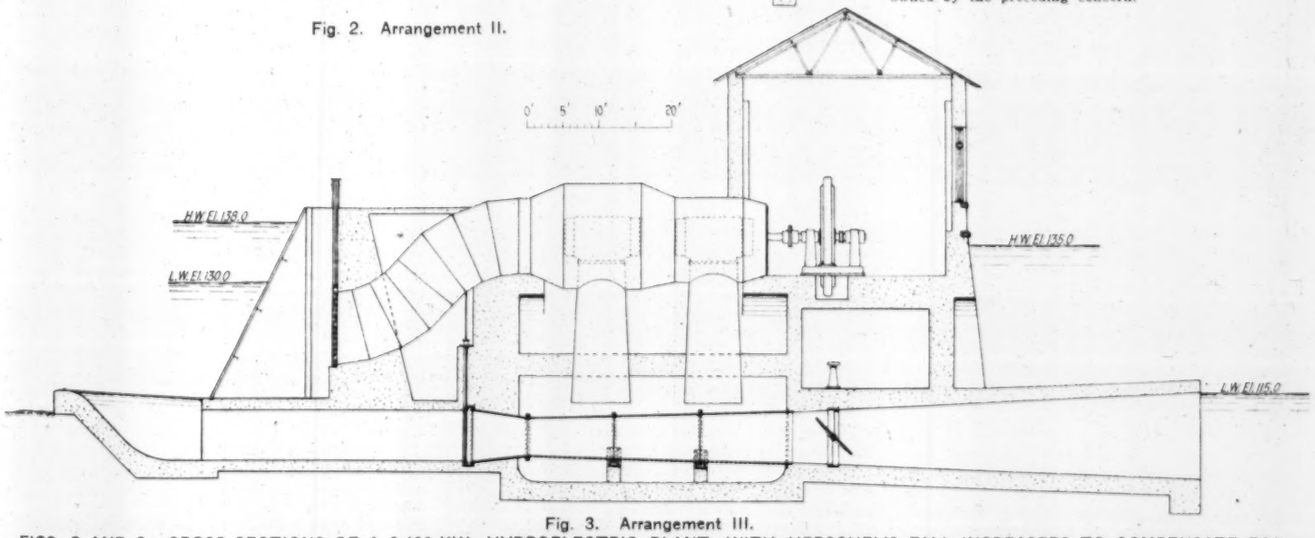


Fig. 3. Arrangement III.

FIGS. 2 AND 3. CROSS SECTIONS OF A 2,400-KW. HYDROELECTRIC PLANT, WITH HERSCHEL'S FALL INCREASERS TO COMPENSATE FOR BACK WATER.

NORWEGIAN ATMOSPHERIC NITROGEN INDUSTRY.—According to a report from the British Consul at Christiana, the rapid extension of the Norwegian industry means an expenditure of $15,000,000. Two processes are in important use—the Birkland-Eyde (see Engineering News, Jan.-June, 1907, p. 150) and that of the Badisch Analin und Soda Fabrik (See Engineering News, July-Dec., 1909, p. 500). Some $6,000,000 has already been expended on the electro-chemical works at Notodden and Svaelgfos and the power plants at Rjukan and Vanuna. These projects will be completed by 1911. The value of output of artificial nitrates for 1908 was $536,000 and the total cost of production was $402,000. The following companies operate or are building works for the fixation of atmospheric nitrogen.

(1) Norak Elektrisk Kraelstof Aktieselskab, of Christiana (owners of Notodden Saltpeterfabrikker. French capital, $7,890,000.

(2) Vammatos Aktieselskab. Half of the capital is owned by the preceding concern.

(3) Rjukanfos Aktieselskab. One-half the capital ($3,377,600) is French and the rest Scandinavian and German. The shareholders of the first named company are interested.

(4) Christianssands Elektrokemiske Aktieselskab. This is the property controlled by the Badische Analin und Soda Fabrik, of Germany. The capital is $53,600.

Proportioning Latticed Columns by Weight Per Foot.

By BENTON LATTIN.*

In the analysis of column strength, there are certain things that differentiate a latticed column from a column with a solid, massive cross-section. The unity of a latticed column is not a fixed unity as in a massive column, but depends upon its lacing bars—which serve mainly to prevent the webs or main members from sliding one along the other under stress—and upon its transverse or longitudinal diaphragms, which serve to resist respectively twisting and local buckling. These lacing bars and diaphragms are more or less effective according to whether or not they are of a suitable sectional area, and of suitable arrangement, length, etc.

INFLUENCE OF LACING RATIO.—In the first place let us consider how the strength of a latticed column depends upon the sectional area of its lacing bars. Consider a number of columns, as sketched in Fig. 1, all of equal lengths, breadths, and weights. Let these weights be differently distributed between webs and lacing in the several cases. Some of the columns, as A and B, have heavy webs with slender lacing, and some, G and H, have light webs with heavy lacing. In this series the column with flimsiest lacing (Column A) lacks unity because its lacing bars are not stiff enough for their purpose. Column A under stress behaves partly as two independent webs each acting as a slender column. For that reason it is weak. On the other hand, the column with heaviest lacing (Column H) has the best unity of all, but at a great sacrifice of metal from the webs. For that reason Column H is weak.

Between the extremes there is one column, say Column C, with such a degree of unity, on the one hand, and such percentage of area in the webs, on the other hand, that it is the strongest of all. The lacing bars of this column constitute a certain percent of its whole weight. A considerable change in this percent would affect the strength but little, as in all maxima and minima. That is to say, in the series sketched by Fig. 1 the columns C, D and E are about equally strong, although B has much heavier webs, i. e., a greater cross-sectional area as ordinarily regarded, than Column D.

This comparison shows that the strength of a good latticed column depends not upon the area of its webs, but upon its gross cross-sectional area, or in other words upon total volume of column (including lacing bars) divided by length. Or, the strength is proportional to the mean weight per foot.

If, for example, we have two columns each weighing 100 lbs. per ft., one having say 75 lbs. in main section and the other, 80 lbs. in main section, both being (we will assume) somewhere near the proper ratio of distribution and of good type of details, then they should be credited with equal strength. In contradistinction to this, ordinary practice would allow the second column about 7% more load than the other, ignoring the fact that its lesser degree of transverse connection weakens it by the same degree that its greater web-area tends to strengthen it.

*5199 Ridge Ave., Philadelphia, Pa.

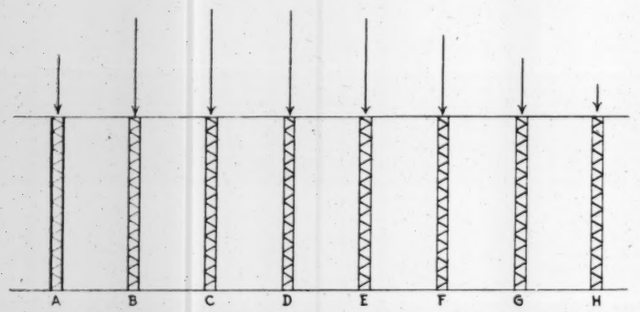


FIG. 1. A SERIES OF LATTICED C OLUMNS WITH VARYING RATIO OF LACING.

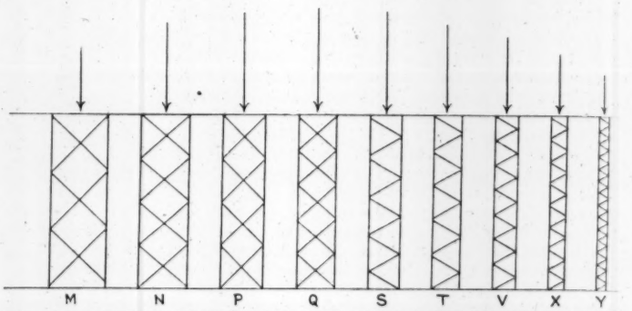


FIG. 2. A SERIES OF LATTICED C OLUMNS WITH VARYING WIDTH.

INFLUENCE OF LENGTH-RATIO.—In the second place, consider how the strength of a latticed column depends upon its slenderness. Take a number of columns, Fig. 2, of equal lengths and equal weights, and each with the proper distribution of metal between webs and lacing to give maximum strength. Let some of these columns be broad, as M and N, and some narrow, as X and Y, in a regular sequence of variation. The drawing Fig. 2, for the sake of clearness, does not show the slenderest columns as narrow as they should be taken; the lower end of the series should include columns up to or beyond the limits of slenderness usually permitted in practice.

In this series the broadest column, M, lacks unity because it has few lacing-bars, too few to prevent the webs from sliding past each other when stressed. Under load this column is much like two independent webs acting as separate columns. Hence it lacks strength. On the other hand Column Y, the slenderest of the series, has the best unity of all, because its webs are effectually held in fixed relation to each other by the many lacing-bars; but it has this unity at a sacrifice of stiffness of the column as a whole, being excessively slender. Hence it also lacks strength.

Between the extremes there is a Column Q of such proportions that it is the strongest in the series, having the best combination of unity and integral stiffness. Column Q has a certain ratio of length to breadth (or radius of gyration), which thus is the most favorable ratio. But a considerable change in the ratio of length to breadth, either increase or decrease, would affect the strength of the column but little, as in all cases of maxima or minima. That is, in the series Fig. 2 the columns P, Q, S and T are about equally strong, although P is very much broader than S or T. This shows that the strength of a good latticed column is independent of the ratio of length to radius of gyration, within considerable limits.*

A curve plotted between unit-strength and length-ratio L/r for a latticed column should, because of the varying degree of unity above referred to, exhibit two maxima and a minimum, in the writer's opinion. This curve is markedly different from the column curve for a solid column. Fig. 3 shows the two curves side by side, with an intermediate curve applicable to a thin-walled column of closed section, i. e., not latticed.

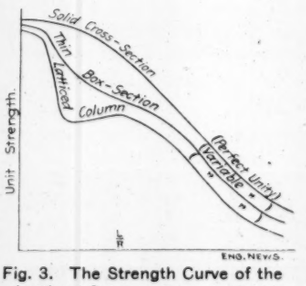


Fig. 3. The Strength Curve of the Latticed Column, Compared with the Curve of the Solid Column.

THE EFFECT OF DIAPHRAGMS.—If a latticed column be not braced by transverse diaphragms, the two opposite edges of a web may deflect in opposite directions, Fig. 4. The column may twist in the middle, in other words. When a column behaves thus, its web plates, by getting warped out of a plane surface, must lose some of their strength. We may take another column of the same length and weight as that shown in Fig. 4, but with some of the metal put into transverse stiffeners. By preventing kind of failure of Fig. 4, this new column is m the stronger. Thus, there must be a cert ratio of distribution of metal between lacing-b and cross diaphragms that gives maxim strength for a given total weight of column; b as before, a considerable variation from t most favorable ratio will not change the stren materially.

SUMMARY.—(1) If the metal of a column suitably distributed between webs, lacing-b and diaphragms, its strength is proportional its mean weight per lineal foot, or to its gr cross-sectional area (total volume, includi webs, lacing-bars and diaphragms, divided length). This result is not restricted to a pr cise ratio of distribution of metal, but holds t within a considerable range of ratios.

(2) There is one ratio of length to radius gyration that gives a latticed column its great strength per unit of gross area. Within a considerable range either side of this most favorable ratio the strength of the column is independent of its radius of gyration.

*An exception to this would have to be noted in a case where limiting conditions compel the adoption of a distinctly unfavorable length-ratio.

A FABRIC-AND-FELT WATERPROOFING has been brought out, as a means of securing greater strength against accidental mechanical injury of waterproofing courses in concrete and masonry work, or in multiplex felt roofing. The body of the sheet is a cotton-and-wool felt (commonly called simply wool felt) impregnated with coal-tar to a weight of 14 to 15 lbs. per 100 sq. ft. One side of this is faced with a closely-woven cotton drill, which is cemented to the felt by a layer of tar somewhat softer than that used for the impregnation. The cementing tar penetrates partly into the mesh of the drill, giving tight adhesion. The fabric (made by the Barrett Mfg. Co., of New York) is named "Tartex." The makers recommend it for use where the waterproofing course in masonry is placed while other work is going on, laps of the waterproofing where left exposed for a time may be torn or broken so that it will be difficult to make a reliable lap later. One or more layers of Tartex used in place of the same number of layers of the regular felt are recommended in such cases. The material costs considerably more than plain felt, but this, it is claimed, adds only a small percentage to the total cost of the waterproofing. Samples may be had from the makers.

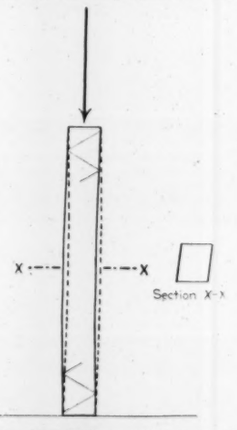
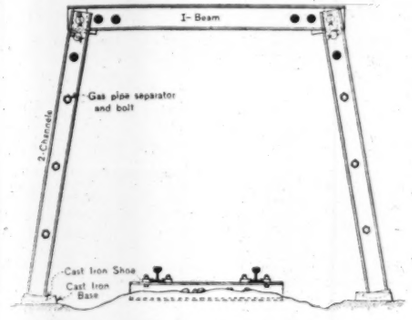


Fig. 4. Failure of a Column by Twisting of Webs.

The Use of Steel for Mine Timbering.*

By R. B. WOODWORTH, M. Am. Soc. C. E.†

The first use of square timber sets of structural steel shapes for main headings seems to have been made in 1907 at Stearn's Shaft, Susquehanna Coal Co., Nanticoke, Pa. The conditions which caused their use were large spans at the foot of the shaft and great pressure under which 24-in. yellow pine timber collars lasted only about eight months. These timbers are still in position and in excellent condition, exposed to constant contact with mine water without signs of failure or corrosion and without other protection than good heavy coats of paint. They were constructed in the form shown in the publications of the Carnegie Steel Co. as "Steel Gangway Support, Style A," in which the collar



Pin Bearing, I Beam Girder, Double Channel Struts, Cast Iron Base

Fig. 1. Steel Gangway for Mines. Style A of the Carnegie Steel Co.

is composed of a standard I-beam which frames at each end between two channels separated by gas pipe separators and resting at their bases on a cast-iron shoe of circular form which in turn fits into a cast-iron base, as shown in Fig. 1. Pin connections are used at the top of the legs, one passing through the beam and channels and the other through the channels only. Steel wedges are driven under the collar so as to distribute the weight on both pins. In this form of construction, for a standard single track gangway it is necessary to assemble 31 pieces and the cost is comparatively high. An installation of this character, however, can be adapted to almost any requirement of strength, and large stretches of steel timbered gangway in the anthracite region are timbered after this design. In one installation, for instance, the collars are 12-in., 31.5-lb. I-beams 12 ft. long, the legs are composed each of two 8-in. channels and the cotter-pins are 1¾-in. in diameter. The sets are lagged in part with 30-lb. rails and in part with lumber. The simplicity of the construction is shown in that the plain material was bought from the rolling mill and the fabrication was done in the coal company's own shops.

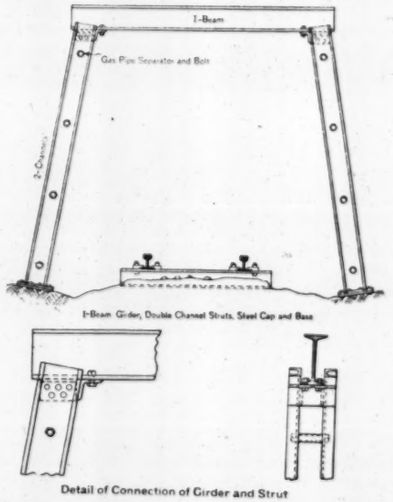
The three-piece wood gangway supports used in square timbering are not adjustable and, therefore, the adjustability secured by the use of Steel Gangway Support, Style A, seems to be needless and uneconomical. Steel Gangway Support, Style E, (Fig. 2) shows a simpler form in which the strength of the double channel leg can be used in combination with an I-beam collar. In this form the two channels forming the legs are connected together in the shop by bolts and separators. They carry angle brackets at their tops on which the beam rests and to which it is connected by bolts, to permit easy removal, and rest at their bottom on a steel plate to which bars are riveted forming slots for holding the channels in position. In this form of construction there are only five pieces to be erected; the single beam collar, two legs and the base plates. If the footing is good, even the base plates can be eliminated. The angles riveted to the webs of the channels transmit the load from the collar to the legs and the bent angle brackets prevent undue side motion.

The ideal form for simplicity and economical construction is to be found in Steel Gangway Support, Style F, (Fig. 3) consisting of an I-beam or H-section collar, two H-section legs with lug angles at the top thereof to prevent side motion and absolutely plain plates for bearings. If the plain plates are omitted, there are practically three pieces to handle. The set can be put together on the ground and raised into position with minimum difficulty, and in this form the steel square timber set is the exact equivalent of the three-piece wooden set in such common use. The first sets of this design used in the United States were installed in October, 1907, in the pump house of the Midvalley Coal Co. at Wilburton, Pa., and the steady demand for them indicates their perfect adaption for the usual purposes of gangway timbering.

The bent lug angle which prevents lateral motion may be replaced by a steel bar, and sets of this character may be found, among other places, in the Maxwell Colliery of the Lehigh & Wilkes-Barre Coal Co. In fact, the ease with which steel can be adapted to any condition of service is exemplified in the various simple modifications which have been made in the construction of mine timbers. The ideal steel mine timber of the future will be that in which unnecessary refinement will be eliminated. It need not be any more adjustable than the three-piece wooden set and, like it, will possess extreme simplicity and economy in manufacture.

LAGGING.—Many kinds of lagging have been used with gangway supports of steel. In Eureka Mine No. 36 of the Berwind-White Coal Co., for example, the 125 sets of "Style A Gangway Supports" now in place have been lagged with wooden sheeting and extra wooden planks put on the outside of the curve where these sets are used. In some cases short round poles were used. A most excellent installation would consist of thin concrete slabs of slight depth made on wire netting or expanded metal and placed in between the flanges of the beam so as to permit easy removal if broken. The wide flanges of the H-sections offer peculiar advantages in this respect. The pump house of the Midvalley Coal Co. at Wilburton, Pa., in which were placed the very first H-sections rolled in the United States, was lagged with old rails and planks. The use of ⅝-in. boiler plate has English practice to commend it, and corrugated iron might also be employed with advantage in situations where moisture conditions did not raise any presumption of early corrosion and where, for that reason, increased thickness of metal might not be desirable.

REDUCED COST.—A pound of steel in beam shape is, roughly speaking, equivalent in strength to a board measure foot of the best southern yellow pine or white oak. Under present market conditions the cost of steel in Pennsylvania is about twice the cost of the wood used in square timber sets, so that if the first cost of the installation is considered, the advantage will lie with the wood. Where, however, the gangway has to be maintained over a number of years and the workings are in any way permanent, consideration should be had to the capitalized value of the material as compared with the first cost of installation and steel will be found economical in most cases on the basis of ultimate cost by reason of its long life and endurance. In the Maxwell Colliery of the Lehigh & Wilkes-Barre Coal Co., double track gangway sets, consisting of 24-in. round yellow pine collars 17 ft. long, with legs 10 ft. 6 ins. long, were replaced in 1908 by 20-in. 65-lb. beam collars carried by 8-in. 34.6-lb. H-section legs. The cost of the timber sets was $15 erected; the cost of the steel sets erected on concrete bases was $40 each. Capitalized at 6% compound interest on the very low assumption of 15 years' life, the cost of the steel set at the end of the 15 years will represent an investment of $95.86; during the same length of time, based on past experience, six wooden sets will be required at a capitalized value of $153.56. At the end of the time the value of the wood will be nil, while at the present market price of scrap the steel will be worth $12.03. On this basis the saving on the steel can be set down at $89.73 per set, which means a saving per set per year of $4.65.



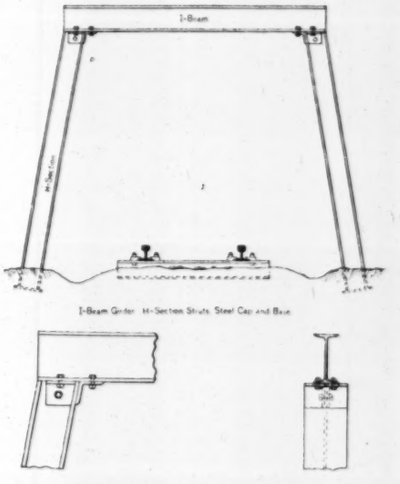
I-Beam Girder, Double Channel Struts, Steel Cap and Base

Detail of Connection of Girder and Strut

Fig. 2. Steel Gangway. Style E, Carnegie Steel Co.

REDUCED EXCAVATION.—By the substitution of steel for wood in this particular instance, 4 ins. of headroom was gained and 32 ins. in width. That is to say, had the steel been used for wood in the first place, the excavation could have been made 4 ins. lower and 32 ins. narrower; quite a large item where the headings are driven partly or entirely through rock. At the Adrian Mines of the Rochester and Pittsburg Coal & Iron Co. 4-in. H-sections took the place of 8-in. timbers, resulting in the saving of 4 ins. of headroom, and the item is worthy of consideration in connection with the first cost of material.

REDUCED ERECTION COST.—The reduction in weight to be handled effectuated by the use of steel is an item of large importance, leading to cheapness in erection and, therefore, reduction in first cost, inasmuch as all the timber for underground work has to be handled down the shaft or over the tracks. The wooden timber sets for the Maxwell Colliery, discussed above, required the handling in erection of 126 cu. ft. of wood weighing approximately 6,280 lbs., whereas the steel weighed 1,690 lbs. With the steel there is no handling of excess material, as it is furnished by the manufacturers ready to assemble at the mines without waste, whereas the wood has to be framed with consequent delay in time and loss of material.



I-Beam Girder, H-Section Struts, Steel Cap and Base

Detail of Connection of Girder and Strut

Fig. 3. Steel Gangway. Style F, Carnegie Steel Co.

FIREPROOF CHARACTER.—The use of steel mine timbers is to be recommended on the score of commercial and humanitarian reasons, as already intimated, at least at pump houses, stables and at the foot of shafts and other points where its use in situations exposed to fire will obviate to a large extent the destruction of life and property, and there is no need to expiate further on its advantages in this direction, as the same results which have followed its use above ground will necessarily be true in its use under ground. The use of steel will not of course prevent fires from gas explosions, but it has already demonstrated its usefulness in mines where explosions and fires have occurred, as, for example, at the Courrieres Mines in France, and though it is possible to displace it and bend it so as to require re-straightening, it cannot catch fire and the blowing down of a few sets by explosive action cannot occasion the caving which comes as a result of the burning out of wooden timbers.

RE-USE.—Another item in the use of steel as compared with wood and to be considered by the farsighted mine operator is the matter of re-use. Under present conditions in the United States, props are very seldom withdrawn and are usually utterly worthless when the time comes for their replacement. Timber in wooden gangway supports likewise suffers from the same deterioration, but steel will stand very severe punishment. In England, so far as the speaker is able to ascertain, it is the custom to withdraw and to re-use all timber, and in English mines roof supports have been taken out, turned and re-used 200 times and over; and it has been noted as one large element of its advantage that even when the steel has served its purpose and under heavy roads, which have taxed it beyond its strength, has been so crippled and twisted as to be no longer safe for mine operations, it still possesses a relatively high value for use as heavy melting stock.

DURABILITY.—In the ultimate analysis true economy in mining operations is not so much a consideration of first cost as a question of life and durability; and if there is any argument at all in the position taken as to economic waste involved in the use of timber, the economy of steel due to its long life and durability will be a large feature in the future in the prevention of economic waste. Steel, on the lowest possible calculation

*Extracts from a paper, "Mine Timbering in Steel," read before the West Virginia Coal Mining Institute, Huntington, W. Va., Dec. 7, 1909.

†Engineer, Carnegie Steel Co., Pittsburg, Pa.

of life and the highest possible duration of wood, due to peeling, seasoning and preservative treatment, is truly economical when its first cost can be kept down to three or four times the price of the timber it displaces. The large use of steel in American mines has been so recent that only problematical figures can be given for this durability. The assumptions ordinarily made of a life of 15 years are believed to be exceedingly conservative. The average life of steel props in Warwickshire, Eng., is said to vary from 10 to 13 years as compared with three months for timber, and their life would be very much shorter than the length of their service in square timber sets owing to the more severe handling the props experience in removal and resetting, so that it may be assumed reasonable to expect square timber sets to last as long as required in any one mine however large the property may be and however long it is necessary to maintain the gangway. English practice indicates that by the use of steel a reduction in timber costs may be effected of 2 cts. per ton, which means, under present mining conditions, a reduction of timber cost in the anthracite region from 7.7 cts. per ton to 5.7 cts. per ton, is in itself an item of most careful consideration.

A New Hand-Power Core Drill.

The hand-power core drill shown in the accompanying illustration is designed for prospecting, foundation testing and wash borings. It can be used with either shot or diamond tools and will drill a 2¼-in. hole, cutting a 1¼-in. core, to a depth of 300 ft. Hand-power drills are particularly adapted for use in mountainous regions not readily accessible to the heavier power drills and in places where fuel is difficult to obtain.

The drill illustrated herewith can be readily taken apart for shipment and is especially suited for mule-back or even more primitive means of transportation, as the heaviest single part is the 73-lb. flywheel. It is claimed by the manufacturers, the Terry Core Drill Co., 50 Church St., New York City, that the flywheel, an improvement not previously taken advantage of in hand-power drills, greatly improves the regularity and ease of operation. The flywheel is mounted on the crank-shaft at the opposite end from the crank and a handle is provided near its periphery so that the drill can be cranked from either side, or from both sides at once when more rapid drilling is desirable and in twisting off cores.

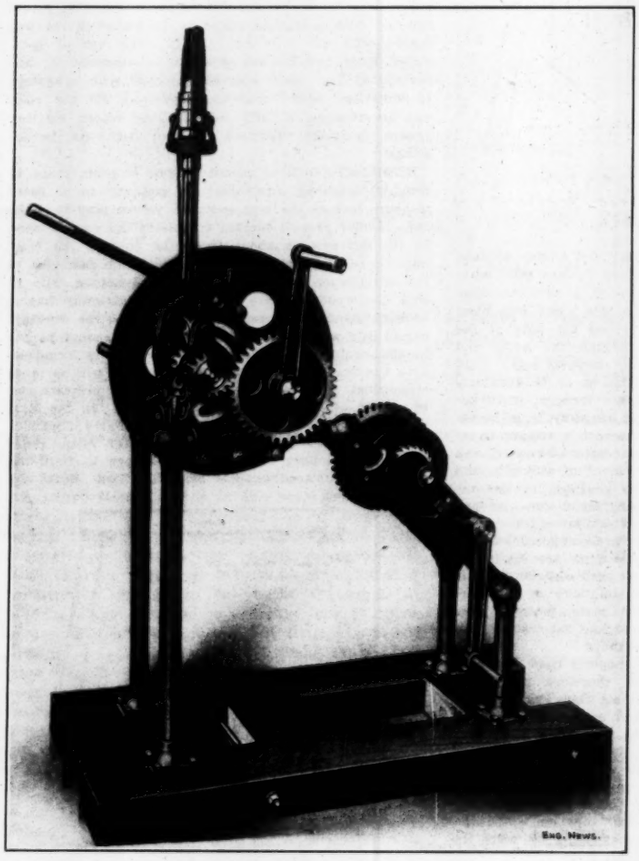
The crank-shaft is mounted in bearings in cast-iron side frames supported by the main frame. The main frame, as shown in the illustration, is made of cold-drawn seamless tubing and the side frames have sleeves at their lower edges which encircle with a sliding fit the horizontal members of the main frame. The feet of the main frame are screwed to a heavy wooden standard. The bearings of the vertical drill spindle are in a separate frame, or drilling head, which is mounted between the side frames on horizontal trunnions. One of these trunnions, the one at the nearer side in the illustration, carries at its outer end a pinion meshing with the cut spur gear on the crank-shaft. At its inner end is a bevel gear meshing with a second but slightly larger gear which drives, through a feather key, the drill spindle. With the spur gears arranged as shown in the half-tone, the spindle makes three revolutions for each turn of the crank. If the character of the material to be drilled requires a slower speed, the gear and pinion can be interchanged. The crank-shaft will then have to make about 2¼ turns to cause one revolution of the spindle.

The spindle has a range of feed of something over 2 ft. and the tubing for driving the core-barrel is furnished in 2-ft. lengths. The feeding device consists of two small drums on a common horizontal shaft actuated by a hand lever through a pawl and ratchet wheel. Two cords or small wire cables are attached to a collar on the water-swivel at the upper end of the spindle and lead from there to the two feed drums. Winding the cords on the drums by means of the feed lever, seen extending to the left in the illustration, forces the spindle downward. The water-swivel runs on ball-bearings and is necessary for the attachment of the hose from the hand force-pump used to supply water to the bore hole. The water is forced down inside the hollow spindle, tubing and core-barrel and comes up around the outside to the surface, carrying the greater part of the grindings with it.

The drilling head may be tipped so as to drill holes at any desired angle with the vertical by loosening the two nuts, one of which is shown in the half-tone at the upper extremity of the semi-circular slot in the side frame. When the nuts are loosened, the drilling head is free to turn on its trunnions and, by tightening the nut, it can be made fast again at any angle. It will be noticed that the spindle bearings are of very generous length. This feature, together with the position of the bearings, one above and one below the point of application of the drive, is intended to steady the spindle and permit a higher drilling speed. Steady motion of the spindle reduces the lashing of the drill rod, especially in drilling at an angle, and thus avoids unnecessary breakage of the cores and increases the percentage of core recovered.

To avoid the necessity of moving the whole machine to give room for driving the casing through loose earth or for raising and lowering the drill rods, the side frames carrying with them the crank-shaft and drilling head, are arranged to be slid back out of the way on the main-frame tubing. The horizontal tubes of the main frame are made long enough to allow several inches of horizontal adjustment of the side frames, whose sleeves can be made to grip the tubing by tightening the nuts along the longitudinal partings on their under sides. The hand hoist mounted on the 45° tubes of the main frame behind the drilling head, is used for raising or lowering drill rods and for driving casing through surface soil.

The drill can be adapted for power work, if desired, by substituting a pulley for the flywheel and adding a countershaft with friction clutch. It can then be driven by a steam or gasoline engine or by horsepower, and the depth to which a 2¼-in. hole can be bored is increased to 400 ft. Holes of larger diameters up to 4 ins. can be bored to lesser depths either by hand or with the power attachment.



TERRY HAND-POWER CORE DRILL.

Reinforced Concrete Aqueduct Lining

By H. E. REEVES.†

The Illinois and Mississippi Canal has in all nine duct bridges, with a total length of 1,829 ft. So the writer is aware, no concrete-lined aqueducts e in 1905, or at the time these linings were built. bridges vary in length from 140 ft. to 350 ft., bu uniformly built in spans of 35 ft., making one ty lining applicable to all of the bridges.

Plans were originally drawn for the trunk to be of steel I-beams with a wooden lining, and the b were bought in the winter of 1904, as it was exp that the contractors would have the piers ready th lowing summer. The wooden linings were not t placed until near the opening of the canal. In Jan 1905, Mr. L. L. Wheeler, Assistant Engineer in ch of the feeder and western section of the canal, des a reinforced-concrete lining. This design was appr As above stated, the spans are 35 ft. c. to c. of p The clear width for the canal is 40 ft. The normal d of water is 7 ft., but the stresses were computed u a maximum loading of 7 ft. 6 ins. The steel frame in the floor consists of 19 20-in., 90-lb. I-beams, 3 11 ins. long, and spaced 27 ins. c. to c., as show the accompanying cut. The beams rest directly on concrete at the piers. Three 1-in. rods, carrying cast cylindrical separators, pass through the webs of the beams giving them lateral rigidity. The side framework consists of two similar I-beams placed horizontally one 6 ft. above the other. They are united by web members forming a three panel truss to support the dead load of the beams themselves and the side lining. The upper edges of the flanges of the top beam are 7 ft. above the canal bottom. On this steel framework the linings were built.

In considering the adoption of reinforced concrete in preference to the wooden lining, consideration was had of the fact that should the canal be unwatered at any time the wood would be exposed to drying out, checking and warping. As a matter of fact portions of the canal have been practically unwatered three times in the two years of its operation. Another consideration leading to the adoption of concrete linings lay in the deflection of the beams. Under the maximum loading the deflection in the bottom beams is ⅝-in. and in the bottom beam of the side frames the deflection is ⅞-in. Under these deflections the difficulty of calking the junction of the sides with the bottom is apparent. A third important consideration developed through the local conditions existing at some of the aqueducts, where the water in the streams at times rises several feet above the floor of the aqueducts, the maximum recorded being 5.7 ft. at Aqueduct No. 5. Should the canal be empty, wooden linings would be unfit to resist the upward and inward pressure thus produced. These contingencies and stresses, not provided for in the timber design, were readily cared for in the concrete design. In addition, the first cost of the concrete lining was estimated to be 20% less than that of wood, with probably much greater durability.

To meet the above conditions the design was worked out as follows: The bottom was made 6 ins. thick, with ½-in. corrugated bars spaced 6 ins. transversely and 9 ins. longitudinally, or two between each pair of I-beams, a beam taking the place of every third longitudinal rod. The tops of the I-beams were imbedded 2 ins. in the concrete of the floor, thus thoroughly anchoring the lining to the beams. The transverse rods were laid upon the tops of the I-beams, and the longitudinal rods were wired to the under side of the transverse rods. The sides were made of concrete 9 ins. thick, placed with the inner face 4 ins. inside of the inner edge of the beam

*Abstract of a paper presented at the annual meeting of the Illinois Society of Engineers and Surveyors, Cairo, Ill., Jan. 26, 28.

†U. S. Junior Engineer, Atkinson, Ill.

in the side truss. Vertical ¾-in. reinforcing rods were used, spaced 6 ins. apart, and bent to an irregular shape so as to come inside of the beams at the top and bottom and to within 2 ins. of the outside of the concrete in the center.

The side trusses are not sufficiently anchored to the piers to resist any great amount of inward pressure, so it was necessary to transfer the horizontal thrust (from external head of water) to the floor system, and to provide for the bending moment at the junction of the sides and bottom. To accomplish these purposes and also to prevent separation of the bottom and sides due to the deflection of the beams, the concrete was built to fill out the angle, as shown. The vertical reinforcing rods in the sides were bent out into this triangular mass of concrete, and the bottom transverse rods were carried entirely across it, thus binding the sides and floor rigidly together. The bending moment, due to the inward pressure, would then be a maximum at the top of the 3-ft. triangular piece of concrete, and the 9-in wall at that point is sufficiently strong to withstand the pressure due to any external head that can occur.

The binding of the floor and sides rigidly together transfers some of the water load from the sides to the floor and from the floor to the sides, thus causing them to act, in a measure, as beams. The floor would, of course, have ample rigidity. In order to develop the strength of the side (including the triangular piece) as a beam, and also to care for the temperature stresses, ¾-in. and ½-in. longitudinal reinforcing rods were used (13 of the former and 9 of the latter). These were spaced about uniformly throughout the section, the ¾-in. rods being placed at the bottom.

The combined weight of concrete in the floor and the submerged floor beams is sufficient to counteract the upward pressure due to about 2 ft. of external head, but as heads of nearly 6 ft. had been recorded, it was very necessary to provide additional safeguards. This was accomplished primarily by bolting the floor to the piers. For this purpose nine 1¼-in. anchor bolts spaced 4 ft. 6 ins. were set along the center line of each pier. These bolts extend to the bottoms of the piers and upward between the floor beams 18 ins., so that the ends of the anchors are just below the bottom of the floor lining. The anchors were capped with nuts and large cast washers. The space between and around the ends of the floor beams and anchor rods was then filled with concrete to a depth of 18 ins., and for nearly the full width of the piers, thus thoroughly anchoring the floor beams. The floor lining at the piers rested directly on this bed of concrete, which was troweled smooth and allowed to harden in every case before the floor lining was placed. Should any expansion or contraction in the floor occur, the lining is expected to slide on this surface.

As an additional precaution against upward pressure, two inlet valves with small collapsible dams were provided at each end of the aqueduct. The valves consist of 6-in. cast-iron pipe set in the anchor concrete at each abutment, their inner or upper ends being covered with flaps which are closed against internal pressure, but which will open under external pressure and allow water to fill the aqueduct to the top of the dams. The dams consist of ten angle-iron brackets, triangular in shape, to the aqueduct side of which 2-in. plank are nailed by means of nailing strips bolted to the brackets. The tops of the dams are 3 ft. above the floor of the aqueduct.

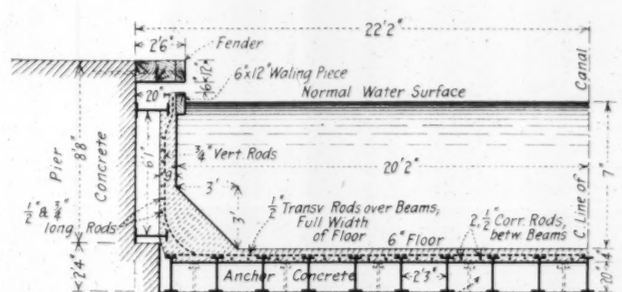
The brackets are anchored to the concrete of the abutments by two small cast-iron pillow blocks. A rod passing through the two legs of the bracket and both pillow blocks serves as a hinge about which the bracket can rotate laterally, when the planking is removed, to a horizontal position upon the bottom. As the concrete to which they are anchored is 6 ins. below bottom grade, the brackets, in this position, are entirely below the surface of the aqueduct floor, and hence free from contact with any passing boat. The bracket on one end of each dam will not fall completely, owing to contact with the side wall of the abutment, but falls sufficiently far to be protected by the triangular piece of concrete in the aqueduct lining. Occasion for the operation of these inlets and dams has arisen once since their completion and their operation has been satisfactory.

To protect the concrete lining against shock and injury from passing vessels, heavy timber fenders were provided, running from pier to pier. These are made up of 12 × 12-in. and 6 × 12-in. timbers, bolted together, as shown. They are anchored to the inner face of the piers by horizontal anchor bolts and set with the upper surface 2 ft. above the normal water surface, leaving an opening of 6 ins. between the bottom of the fenders and the top of the concrete lining, through which water can overflow whenever the stage reaches 7.5 ft.

It may be noted that during the past year portions of the lining at each aqueduct have been cut down to the 7-ft. level, to afford additional precaution against abnormal stages of water which might endanger the canal embankments. The fenders make excellent walks along each side of the aqueduct. As a further protection against boats, or irons projecting from vessels, a 6 × 12-in. waling timber was bolted flush with the top of the lining by bolts passing through the concrete to the flange of the top I-beam of the side frame.

The proportions of the concrete for the lining were 2 cement, 3 sand and 5 fine crushed stone, or 1 cement to 4 well proportioned gravel. The mixture for the anchor concrete at the piers was not quite so rich. The concrete was mixed very wet, and considerable care was taken with the spreading and tamping. The floor was deposited in two courses and in sections running the length of a bay and covering two or three floor-beams in width. The sections joined over the center of an I-beam and no section was allowed to set before its adjoining one was deposited.

Concreting the floor and the sides to the top of the 3-ft. triangular piece, constituted a day's work of eight hours during the early part of the work. The remaining top portion of the sides was placed after the lower portion had set and a part of the forming was removed. The yardage in these top portions was small, and owing to the limitations of forming and the moving of runways and staging, this was not an economical method of operation, besides rendering necessary a horizontal joint at the 3-ft. point on the sides. Later, authority was granted to work ten hours, and (by using a different style of form) the whole lining for one bay was deposited in a day. The surface of the floor was covered with ½-in. of mortar and troweled smooth. No finishing was done on the sides other than to exercise care to secure a dense, hard face.



AQUEDUCT CONSTRUCTION WITH STEEL FRAMING AND REINFORCED-CONCRETE LINING; ILLINOIS & MISSISSIPPI CANAL.

The form construction is often given insufficient consideration in laying out concrete work, frequently being left to the carpenter foreman to work out as best he can. This results in extra work, waste of material, and delays to the concrete gang. This loss particularly happens when the forming is complex, and must in part be carried on simultaneously with the concreting; and also when the forms are to be used repeatedly. On this work the floor forms were very simple, consisting of a 2-in. plank placed between the I-beams and supported by brackets resting on the lower flanges of the I-beams. The brackets consisted simply of a horizontal piece supporting the plank and two vertical pieces extending to the I-beam flanges, with a spreader to keep the bottom ends from slipping off the flanges. To remove these forms it was only necessary to drive out the spreaders, when the brackets and plank would come out without drawing a nail.

The back planks for the side forms were nailed to posts fitted between the I-beams of the side truss. Between the bottom beam of the side and the floor beam a plank was specially fitted and beveled, being held in place by wires passing through to the inside. On the inner face of the sides it was necessary to carry up the planking as the concreting progressed. The planks were nailed to triangular brackets extending to the full height of the sides and held in place by wires and spreaders to the back forms. The tie wires were spaced so as to come in cracks between the planks. Specially sized and beveled plank were used on the triangular piece at the bottom.

As soon as the concrete for the sections of the floor adjacent to the sides was deposited, these sections were covered 3 ft. in width with plank on which was laid a runway for wheeling concrete to the sides. When these were carried up to the top of the triangular pieces, the runway was elevated and widened for a shoveling platform for completing the sides.

The weight of these planks, runways, and platform was sufficient to prevent the hydrostatic pressure from the sides being transmitted under the lower edge of the form and raising the floor concrete. While the carpenters were building platforms and runways, extending forms, etc., the concrete crew was engaged on the opposite side or on a section of the floor, so that the concreting progressed without delay. Between bays a board ½-in. thick was placed. This was afterward cut out with a chisel and the joint poured full of pitch.

A ½-yd. concrete mixer was used, set in the canal trunk near one end of the aqueduct and charged from the embankment above by one-horse dump carts. For filling the nearest bay, the concrete was usually taken direct from the mixer in wheelbarrows. For the remaining bays, a track was laid and a side-dump car pushed by hand conveyed the concrete to a shoveling platform, adjacent to the bay being filled, from which it was shoveled into wheelbarrows and wheeled to place.

An interesting feature of the work was the method used for protection against freezing. Owing to delay in the foundation and pier work some of the lining could not be placed until late in the season and the local conditions were such that it was very urgent that the work be finished without delay. The last concrete was deposited Dec. 28, and the temperature during the final weeks dropped as low as 12° or 15° F., barely rising to the thawing point in the middle of the day. Owing to the thinness of the lining, its exposed position and the importance of the work, considerable care was necessary.

To heat the concrete materials, the exhaust steam from the mixer engine was turned into the drum of the mixer. The exhaust pipe was led to a point in front of the discharging opening of the drum, so that the drum when tilted for discharging would just clear the end of the pipe. The force of the exhaust then carried the steam into the revolving drum, where complete mixture with the dropping particles of concrete utilized practically all of the heat remaining in the steam. This method of heating concrete is unique in the writer's experience and, when it is considered that it involved no expense, the results were really surprising. The temperature of the deposited concrete averaged probably 70°, while if a batch were left in the mixer three minutes or more its temperature would be 90° to 100° F.

To protect the deposited concrete, the inside of each bay at the close of the day's work was roofed over with 1-in. boards laid loosely on wooden horses, the ends being closed with pieces of canvas. Into the chamber thus formed, live steam from the boiler was conducted through a pipe line. The night watchman kept up the steam, the amount needed being very small. Steam was kept on the concrete for two nights, or for about 40 hours after being laid. It was considered that the outside was sufficiently protected by the 2-in. forms. On the third day, the forms (if needed) were removed and the concrete left exposed. The cost of this protection was about 12 to 15 cts. per cu. yd. of concrete, and the results were perfect. As an illustration of the need of protection, it may be noted that the feed pipe for the boiler froze one night about midnight and steam was shut off from the concrete for about seven hours. The concrete froze slightly, and about ½-in. of the surface afterwards shelled off.

Expensive freight and wagon hauls made the price high for concrete work at most points on the canal. The average cost of the lining was as follows, and was about 10% below the estimate:

Concrete per bay	$999.61
Reinforcement per bay	147.26
Total cost per bay	756.87
Cost of concrete, per cu. yd.	9.61
Cost of reinforcement per lb.	.032

The linings are practically water tight. The exterior surface at nearly all points, both on the sides and bottom, is dry under a full head of water. The only place where seepage shows to any noticeable extent is on some of the sides at the top of the triangular piece where work stopped between days. Where the sides were carried up continuously this does not show at all.

Tests of Tungsten Incandescent Electric Lamps.

Since the introduction of incandescent electric lamps, having tungsten filaments (Engineering News, July-Dec., 1907, p. 92), many early faults have been overcome. Where the imported lamps showed a breakage of 60% of the filaments, a breakage of as low as 1% with shipments of American-made lamps is now possible. This is indicative of the general progress.

The latest authentic information comes from a series of tests made by Messrs T. H. Amrine and A. Guell at the University of Illinois. The results of this comprehensive study appear in Bulletin 33 of the Engineering Experiment Station. These tests were made on 100, 25-watt, 110-volt lamps of each of three prominent types, with the idea of disclosing the good and the poor qualities gen-

erally and in particular what might be expected of commercial lamps as regards life, maintenance of candle power and of efficiency in use.

LAMPS TESTED.—One of the types selected was American and two were German, representing three principal processes of manufacture. The filaments of the American lamp were made by the Auer or "paste process, in which pulverized tungsten is mixed with an organic binder, extruded as a filament and heated in an atmosphere of steam and hydrogen. The final filaments are hairpin loops, loosely hung from supporting spires and connected in series.

The filaments of one German type were made by the "deposition" process in which tungsten is deposited on a fine carbon filament from an atmosphere of tungsten oxychloride, is heated to form a carbide with the supporting carbon and reduced to metallic form as in the paste process. These filaments were mounted under slight tension on spring spires, and the whole with stem spires and filament was supported with springs.

The second German type had filaments made by the "colloid" process. A thick colloidal solution, or emulsion, of tungsten is squirted into filaments, dried and heated to a welding temperature in an inert atmosphere. The filaments were mounted as helical loops with auxillary supports to prevent sagging.

The colloid-process filament is seen, under the microscope, as the smoothest of the three. It has a smooth shiny surface broken only by fine check cracks. The paste filament is free from protuberances but is covered with minute wrinkles. The deposited filament is the roughest, being covered with knobs, pits and wrinkles. All three types become roughened after long periods of use and are decreased in size, the decrease being greatest in the deposited type. Filaments used on alternating current were no different from those on direct current.

LIFE TESTS.—For life tests, 50 lamps of each type were selected, 25 being used on a closely regulated constant voltage and 25 being on 60-cycle, alternating-current lines with a badly fluctuating voltage and subject to all the mechanical vibration of the building containing the engines of the university power plant and the machinery of the electrical laboratories. Those used on direct-current were spring supported to protect them.

Under the more favorable conditions at the end of 2,000 hours, there was one colloid-process lamp and one deposited-process lamp still burning and 12 of the paste-process type. With the colloid lamps, failures commenced after 100 hours and continued for 1,500 hours when all but one had failed. With the deposited type failures began at 300 hours and continued steadily until at 1,900 hours only one was left. With the paste type the failures began practically at 900 hours and proceeded at a rate of one each 100 hours.

Surprising comparisons were shown under adverse operating conditions. At the end of 600 hours all the deposited type were burned out, having an average life of only 153 hours. The colloid and paste lamps gave average lives of 434 and 898 hours respectively. The poor results with the deposited type were found to be due to the method of mounting. This was designed to suppress vibrations but instead it held them persistently and set the tightly strung filaments in motion. The colloid and paste filaments, being more loosely mounted did not vibrate, unless placed in a strong magnetic field.

CANDLE POWER AND EFFICIENCY.—All types showed a characteristic increase and decrease of candle power. The paste filaments showed the greatest changes but maintained the highest average. After 2,000 hours use, the average candle power of the paste type decreased to 88% of initial, the deposited type to 89% and the colloid to 77%. The colloid filament was found the least efficient throughout the tests. This was due to the larger number of supports which cooled appreciable areas of the filaments by heat conduction. The deposited-filament lamp under the better operating conditions had a slightly lower efficiency, up to 1,100 hours use than the paste type, but from then on it was slightly higher. This was due to the greater blackening of the paste-filament bulb. These were non-uniform in blackening; some were scarcely discolored after 1,500 hours and others would be as black as an old carbon-filament bulb. The colloid and deposited lamp bulbs blackened uniformly. However none of the lamps on any test showed appreciable discoloration until after 600 hours use.

The accompanying table shows a summary of the results of the life and efficiency tests. Viewed as a whole the tests show that the performance of tungsten lamps may vary surprisingly, according to the kind of lamp and conditions of use. Some lamps give an operating cost, under adverse conditions, as great as with common carbon-filament types. Under the most favorable conditions, however, all the prominent types of commercial tungsten-filament lamps maintain their efficiency with a long useful life—often many times that advertised.

SUMMARY OF RESULTS OF TESTS OF 300 25-WATT TUNGSTEN LAMPS.

	Colloid.		Deposited.		Paste.	
	Conditions, Favorable.	Conditions, Unfavorable.	Conditions, Favorable.	Conditions, Unfavorable.	Conditions, Favorable.	Conditions, Unfavorable.
Mean horiz. CP., new	19.9	20.6	18.6	19.9	19.9	19.3
Mean spher., CP., new	16.7	17.3	13.6	14.5	15.6	15.1
1,000 hrs.	15.3	....	14.4	....	16.3	16.2
2,000 hrs.	12.6	....	12.2	....	15.0	....
Av. watts per lamp	27.5	27.4	28.0	28.0	27.7	27.0
Av. initial watts per mean S. CP.	1.65	1.58	2.06	1.93	1.77	1.83
Av. life, hrs.	762	434	1,167	153	....*	898
Av. horiz. CP. through life	18.2	20.2	19.5	22.5	20.9	22.5
Cost lamps.	1.08	1.08	1.35	1.35	0.85	0.85

*The paste lamps under the favorable conditions showed 12 lamps burning at the end of 2,000 hours. The average life of the 13 burned out before that time was 1,335 hours. Assuming an average life of 2,400 hours, for those left burning at the end of 2,000 hours, the average life for the whole 25 tested is 1,885 hours.

Proposed Rearrangement of Railway Terminals in Chicago.

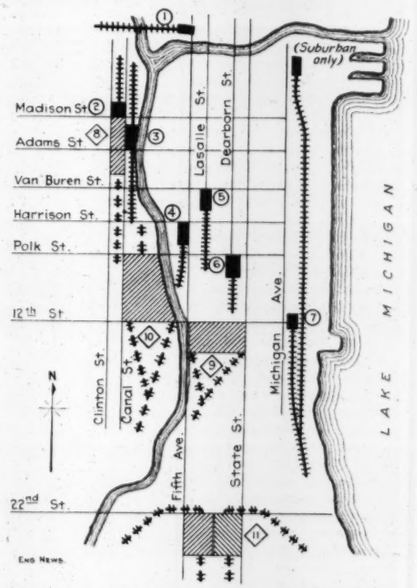
A comprehensive rearrangement of the railway terminals in the city of Chicago, and a concentration of main-line passenger terminal facilities at one immense union station some distance from the present congested business district (but convenient to what is predicted to be the future enlarged business district), has been proposed by Mr. Leroy L. Hunter, an engineer in the city's Department of Public Works. His plans provide for locating the union station in the area bounded by State St., Fifth Ave., 22d St. and 24th St., and he estimates that in this area a sufficient amount of land could be obtained at reasonable prices.

In view of the enormous traffic due to the concentration of all the railways at this one terminal, the plan provides for two separate, but adjacent stations, one for outbound traffic (extending from State St. to Clark St.), and the other for inbound traffic (from Clark St. to 5th Ave.). Eeach would be 1,200 x 666 ft., with one train floor 21 ft. above the street level and another 21 ft. below the basement floor, some of the railways coming in by viaducts and others by tunnels. The upper train floor would have 28 tracks and the lower one 32 tracks. The main waiting room, ticket offices, etc., would be at the Street level. The baggage and express rooms would be at the basement level, approached by inclined roadways. Office buildings might be erected over the stations.

The track plan is designed to prevent delay and interference due to the switching and reverse movements in disposing of empty trains that have to be handled between the station and the car storage and cleaning yards (which would be located outside of the city). By arranging the approach tracks in loop systems, inbound trains would enter at one end and (when empty) pull out at the other end to proceed to the yards. Outbound trains (empty) made up at the yards, would enter at one end, and (when loaded) pull out at the other end. Allowing 20 trains for each train to load and unload, the 120 tracks would accommodate 360 trains per hour, or one train in and out every ten seconds. About 30 railways would be accommodated at this station.

The terminal is estimated to cost $120,000,000, and would require 4,000,000 sq. ft. of land (at $4); 94½ miles of single track (at $10,560); tunnels for 28 miles of single track, and elevated structures for 39 miles of single track. The great station is intended only for main line trains. The suburban traffic would be handled at the LaSalle Station (built a few years ago and the Northwestern Station (now under construction). The other four existing terminal stations would be abandoned.

Somewhat similar plans proposed by Mr. R. C. Sattley and Mr. F. A. Delano have been noted in our issues of May 30, 1901 and Feb. 16, 1905 respectively. Mr. Sattley proposed a location west of the river, extending north from 12th St. to Harrison St., with a separate suburban station at Taylor St. This plan (like that of Mr. Hunter) provided for through tracks instead of stub tracks in order to avoid congestion of trains. Mr. Delano's plan provided for six parallel and adjacent stations fronting on 12th St., five being east of the river. This "multiple-unit" arrangement was devised to secure a concentration of the traffic and terminal facilities, while avoiding the difficulties incident to the operation of the traffic



Map Showing the Location of the Present Passenger Terminal Stations of Chicago, and Some of the Proposed Terminal Stations.

1. Chicago & Northwestern Ry. (Old Kinzie St. Station).
2. Chicago & Northwestern (New Madison St. Station).
3. Union Station.
4. Grand Central Station.
5. LaSalle Station.
6. Dearborn Station.
7. Illinois Central Ry.
8. Proposed Burnham Plan
9. Proposed Delano Plan.
10. Proposed Sattley Plan.
11. Proposed Hunter Plan.

A. Burnham Plan; Stations 7, 8 and 9.
B. Hunter Plan; Stations 11, 5 and 2, (Nos. 5 and 2 for suburban traffic only).

of a number of railways in one enormous station. Each station would be for two or more railways, as in the existing terminal stations.

Various other plans have been proposed, some by the railways and others by independent designers, but in most cases these provide for improvements on existing sites. The "new Chicago" plans prepared by the Burnham commission include the Delano plan already mentioned, but supplemented by three stations in the strip of ground between Canal and Clinton Sts. on the west side, and retaining also the present Illinois Central Ry. station. The present and proposed stations are shown in the accompanying map. The reconstruction of the Union Station on the present or a neighboring site has bee proposed many times, and tentative plans have been made for reconstructing the Dearborn Station on its present site or at 12th and State Sts. (a part of the site proposed by the Delano plan). We have commented on this in our editorial pages.

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It is seven years ago this month that the plan for a great Engineering Societies building in New York City, which had been for years a dream in the minds of a few enthusiastic engineers, became a practical possibility through the generous offer of Mr. Andrew Carnegie. Partially in celebration of that event, the governing boards of the three Founder Societies gathered last week at a dinner.

It is interesting to recall now not only the glowing hopes of benefit to the profession, entertained by those who believed in cooperation between those engaged in different fields of engineering works, but also the pessimistic prophecies of failure and disaster. It is gratifying to realize that the hopes of those who believed in the enterprise have been splendidly fulfilled, while the prophecies of failure have come to naught.

It was the hope of those who planned the building that it would become not only a joint headquarters of the three great National Societies, of Mechanical, Mining and Electrical engineers which assumed the responsibility for the enterprise, but a center as well for the many other technical societies in New York City. That hope has been splendidly fulfilled. The trustees report shows that last year no less than 52 different societies made use of the building. In fact, practically all the space available in the building for Society offices is now occupied. Experience has shown that the demand for Society offices is in excess of the demand for lecture rooms, and the plan is being canvassed of converting some of the space on the sixth and seventh floors now used as assembly rooms and lecture rooms into additional offices.

From the financial side, too, the building is proving most successful. The prophecy that the expense of operating so large and fine a building would prove too heavy a burden has not been fulfilled. The assessments made on the various societies to cover the running expenses are, in fact, far less for the space occupied and facilities afforded than would have to be paid in any ordinary building; but the receipts last year from these assessments were about $10,000 in excess of the running expenses. This excess is being applied to the accumulation of a reserve fund and to investments in additions and equipment.

The original cost of the building, in round figures a million and a half dollars was paid, it will be remembered, by Mr. Carnegie. The three Founder Societies purchased the land on which the building stands at an expense of about $540,000, and have since paid off $317,000 of that amount, leaving about $223,000 still to be paid. This is, of course, a very small incumbrance on a property representing an investment of over two million dollars; but plans are being canvassed for raising funds to pay off this balance.

But the financial success of the enterprise, essential though it be, is after all less important than the chief aim which the original promoters had in mind—to foster cooperation and fraternity between the different branches of the profession. Most emphatically has the occupancy of a common home aided the growth of this spirit. And every engineer who achieves high position in his profession realizes the great personal and professional gain in knowing something of the work of other branches of the profession than his own, and in personal acquaintance with the men who are doing this work.

Some interesting figures regarding electric-railway operation collected by the United States Census Bureau, show that during the five years from 1902 to 1907 the average consumption of energy per car-mile increased nearly 50%. In 1902 the average consumption per car-mile was 1.98 KW.-hrs.; in 1907 this had increased to 2.94 KW.-hrs. This change well reflects the conversion of rolling-stock which took place during that period. An enormous number of the old-fashioned light four-wheeled cars, many of them introduced when electric traction was first installed, were thrown out of service and replaced by modern cars of large weight and large passenger capacity.

It is sometimes argued that electric railways have gone too far in the adoption of large and heavy rolling-stock. The figures above quoted, however, do not support this idea. If we assume the cost of power to average 1½ cts. per KW.-hr., the cost of the power to operate the small cars of 1902 was 3 cts. per car-mile. At the same rate in 1907, the power would cost 4½ cts. per car-mile. Actually, however, with the use of large-capacity cars came the introduction in the power stations of large steam turbines and other radical improvements which have greatly reduced the power cost per unit of output. It is quite likely that on many roads the cost of the power required to operate the heavier cars is little if any more than the cost for the smaller cars run five years earlier.

The Census Office statistics are interesting from another point of view for their indication of the average power required to propel electric cars. If we assume an average speed of six miles per hour, and that 50% of the power delivered to the station bus-bars finally appears as mechanical energy on the car axles, it appears that in round numbers the cars of 1902 required on the average about 8 HP. for their propulsion, and the cars of 1907 about 12 HP.

The readjustment and rearrangement of railway terminal passenger stations is one of the difficult problems with which several large cities are now struggling. It is not so difficult to lay out on paper a system of railway terminals which will promise great advantages over present facilities. The difficulty arises from the necessity of providing for conditions of the remote future. If millions of dollars are to be spent on a new passenger terminal, then it ought to be located where it will best serve the city of twenty or thirty years hence. In many cities it is extremely difficult to foresee the radical changes in location of the business district which may occur in a score of years. An even greater difficulty is involved, however, in securing the active cooperation and agreement of the numerous railways involved, as well as the other interests such as the city officials, the commercial interests and the real estate owners.

The above remarks are suggested by a plan which has been put forward recently for the entire rearrangement of the railway passenger terminals of Chicago, and the establishment in that city of one immense union passenger station. The plan in question is described elsewhere.

It is one of the peculiar conditions of Chicago that its business district has for many years been concentrated within a small area, increase in accommodation being provided by the construction of lofty office and mercantile buildings to replace older and lower structures. In other words, additional accommodation is provided by increase in density rather than by increase in area. This is one of the main causes for the great congestion of street traffic in that city. It seems inevitable that at some time, perhaps in the near future, there will begin a movement to extend the area of the present business district, and when it begins there will probably be a rush to open up the new district. Extension of the business district toward the north and west is restricted by the river, but no such obstruction exists to bar a movement southward.

The designer of the plan above referred to believes that the business district, which now extends but little south of Van Buren St., will extend to 22d St., a distance of nearly 1½ miles farther, and he proposes to locate the union passenger station at that point. This would be for main-line service only, however, two of the present main-line terminal stations in the business district being retained for suburban service. This proposed location brings up the old question whether main-line stations should be located in the heart of the city's business center, or at some distance therefrom. There appears to be a preponderance of opinion in favor of the former plan, though how far this is based upon careful consideration of the question it is hard to say. Most of the numerous plans proposed for the readjustment of Chicago's terminals have adhered pretty closely to the improvement of existing sites (with enlargements involving great cost for land).

Mr. F. A. Delano some years ago proposed a location as far south as 12th St., but one of the strong objections to his plan was the distance from the business center. The Burnham "city beautiful" commission later proposed the same location, however, and according to report there is indecision as to whether the proposed new Dearborn Station should be on the present site at Polk St., or on a new site as far south as 12th St. The new Hunter plan, described elsewhere in this issue, is still more radical in recommending a site still farther south, at 22d St. This is quite outside of the present business district, but the designer believes that the district will extend to that limit at least, and that a main-line terminal should be located on the border of, rather than in the center of, the business district.

The immensity of the scheme referred to may be gathered from the fact that about 30 railways are involved and the cost is estimated at $120,000,000. The task of persuading so many interests to join hands in accepting and carrying out a scheme of such magnitude and such expense seems too difficult for accomplishment, especially as some of the railways have already expended great sums in new terminals and stations, while others are proposing similar expenditures on plans of their own.

We have noted before* how, with the decline of the old apprentice systems in America, many bright boys who might have had a broad training as mechanics have been made machine specialists and how many less alert, or less fortunate, too often have been forced into the ranks of unskilled labor. We have noted that too few manufacturers have been anxious to give their future employes that broad training in a trade which was most desirable for employer and employed alike.

A notable change from these conditions and a good example of our new apprentice systems, is shown in the paper, reprinted elsewhere in this

*Engineering News, Oct. 14, 1909, p. 412.

issue, by Mr. M. W. Alexander, of the Lynn Works of the General Electric Co. Nowhere has a more comprehensive scheme been evolved and nowhere, we believe, has a manufacturer shown greater confidence in his system and greater profit from it. As Mr. Alexander has shown,

> the unskilled worker receives a training adequate to his immediate needs. The grammar-school boy is initiated into the trades with educational instruction of a high-school character. The high-school graduate is trained for semi-professional service with education of collegiate grade. The college graduate is prepared for professional service of the highest order with educational instruction assuming the character of a post-graduate course.

The Pioneer Inventors of the Steamboat.

It is proposed to rebuild, in permanent form as a memorial to Robert Fulton, the attractive temporary "water gate" erected on the Hudson River at One Hundred and Tenth St., New York City, for the reception of naval guests during the Hudson-Fulton celebration, October last. A preliminary architectural competition for the structure closed on Jan. 6. (See Engineering News, Jan. 13, p. 44). The final competition closes March 1.

It is fair to raise the question, why such a pavilion, should be made the memorial of a single great man, when it more fittingly would commemorate a historical group of which he was but the last and the most successful member. Robert Fulton had, we believe, great constructive genius and good business ability rather than rare inventive faculty. The successes which his steam boats attained were the result of a good sense of proportion, of ability to coordinate the details of a design and to secure a commercial organization.

Great as these qualities are, Fulton's possession of them does not seem to warrant adding one more to his many monuments, when we have here the first opportunity to commemorate the whole group of inventors who made steam navigation possible. Why not give some place to the name of each inventor whose contribution was definite and monumental, so to speak? Why not display on the pavilion the long international line of inventors that culminated in Fulton; Hulls, Rumsey, Fitch, Morey, Symington, Evans and Stevens?

Why are these names selected from the long list of those who at sometime or other during the last decade of the 18th century and the first decade of the 19th, toyed with the fascinating problem of steam navigation? In order to answer this question it seems worth while to review briefly the most significant events in the development of the steamboat, aside from Fulton's work.* This is especially worth while because the recent revival of interest in these early engineering works has thrown a new light on old records and indeed brought a few neglected records to the light.

Some records of these early efforts conflict in important dates and details and even authentic contemporary statements are open to interpretations favoring one inventor or another. It is difficult, even with the perspective of a century, to allot to each pioneer his proportion of credit.

Many say that Fulton "invented the steamboat," while many others claim that it was either Rumsey, or Fitch, or Morey, or Symington, or Evans, or Stevens. In truth, it was all of these (and others). The final success of the steamboat was the result of many inventions and not a single stroke of genius. A similar condition prevails in connection with the "invention" of the steam engine and indeed in most fields of human progress. Watt has been called "the father of the steam engine" in spite of the discovery of the Marquis of Worcester and the inventions of Savary and Newcomen.

The steamboat was a dream for a century before it became a reality. A French physicist, Denis Papin, famous in the early annals of the steam engine, is reputed to have proposed a steamboat for the Seine in 1695 and to have run one on the Fulda, in 1707, only to have it broken up by jealous boatmen. We read that two other Frenchmen, an Abbe Arnald and a Marquis Juffroy, tried to solve the problems in 1781 and 1782. But such men must stand here as mere names. If they made any definite contribution, it is lost to sight in the general record of development.

The hydraulic jet is conceded to have been the earliest means of propulsion in the series of boats which led up to Fulton's "Clermont." It was suggested by a Dr. John Allen in England in 1726 and tried later, without steam power. The first definite knowledge of such a device, steam driven, comes from the work of James Rumsey, of Sheppardstown, Va., beginning about 1782. He was a millwright who owned a farm in Berkeley County, Va., on which there was a small pond. It is probable that he started with some mechanical poling device, not steam driven. His design of a steamboat driven by a hydraulic jet was completed in 1785, and the boat was publicly exhibited, on the Potomac at Sheppardstown, according to published statements of residents of the country.

In 1784 Rumsey was given a monopoly grant of navigation on Maryland waters, and in 1785 he obtained patents on his inventions from the states of Maryland, Virginia, Pennsylvania and New York. But apparently he was quite unable to place his invention on a successful commercial basis in America. At any rate, he went to England later and was enabled to build a boat like his Sheppardstown model for trial on the Thames. At about the time of its completion Rumsey died, late in 1792, or very early in 1793, after he had given a public lecture on his invention. His boat was tried after his death, it is recorded, and "made many trips on the Thames at four miles an hour against the wind."

Rumsey's letters, written in England, told about a young American who was there studying engineering and who was greatly interested in Rumsey's boat. The inference has been that this was Robert Fulton, and there seems ground for this, as Fulton went to England in 1786 and in 1796 adopted there the title of "Civil Engineer."

Rumsey generated steam in a coil of pipe called then a "worm," in resemblance to the worm used in distilleries, and this invention held the germ of the idea which was developed into the water-tube boiler by John Stevens in 1788 and later.

Paddle-wheel trials followed the jet idea, and because the "Clermont" used paddle-wheels many believe the prior rights of several inventors were infringed. But the mere use of paddle wheels had little novelty. Legends tell us that the Egyptian and Roman galleys had been propelled by paddle-wheels of some sort, though knowledge of their construction and disposition has not come down to us.

Very often early experiments with paddle-wheels have been recorded as trials of steamboats. Thus there is the persistent legend about Blasco de Garay, a Spaniard, who built a mythical steamboat in 1543—before the expansive power of steam was discovered. This legend, it has been ascertained, had origin in a few trials of a paddle-wheel device for large boats. Capt. Savary also has been called a steamboat builder because of his plan to use manually operated paddles at the time he brought out his pumping engine, but distinct from that. It might be expected that trials of mechanically operated oars or paddle frames would have generally preceded paddle-wheels. However, such seems not to have been the case, and paddles were subsequently used by several who discarded wheels with a feeling of general distrust of the latter and inability to find the favorable dimensions and proportions of wheels and hulls.

The first specific knowledge of the application of a steam-driven paddle-wheel comes from the pamphlet of one Jonathan Hulls, of London, published in 1737, and describing an invention patented in 1736. He was a carpenter who planned a portable apparatus to be temporarily placed on sailing vessels to enable them to get into and out of port under adverse conditions. He proposed to hang a paddle-wheel over the stern and to drive it from a horizontal single-acting cylinder. Ropes from the piston passed over ratchet sheaves on the paddle-wheel axle to convert the reciprocating motion to rotary. It is generally believed that Hulls' invention never passed beyond the model stage, though the contrary has been claimed. At any rate, his success was trifling at best.

In 1787 William Symington was engaged, under the patronage of one Patrick Millar, of Dumfriesline, Scotland, an owner of pleasure boats on the Forth and Clyde canal, in equipping one of these craft for steam power. Millar was said to have been a former naval officer and to have developed the idea of using two hulls with a pair of paddle wheels between them worked by manpower. Symington already had a scheme in hand for a steam carriage, but was led to turn his attention to Millar's projects.

The small boat of 1788 on a lake at Dalswinton was sufficiently successful so that in 1789 a larger double-hulled boat 60 ft. long was fitted with engines, built under Symington's direction, which propelled it at a speed of seven miles per hour. The paddle-wheels were worked from two steam cylinders by a rather clumsy chain and ratchet system. Interest lagged, perhaps on account of the cost of operating this inefficient device. At any rate, not until 1801 did Symington resume experiments. This time, under the patronage of Lord Dundas, of Kerse, Scotland, he built the famous "Charlotte Dundas," with a horizontal (or slightly inclined) cylinder, a crank on the paddle-wheel shaft and a direct connecting rod. Symington has stated in his papers that Robert Fulton took a trip in the "Charlotte Dundas" with him and familiarized himself with the management—another instance of Fulton's industry in gaining first-hand knowledge of early steamboat projects.

One whose name has come to hold an important place among these pioneer inventors was the eccentric John Fitch, first of Windsor, Conn., and later of Trenton, N. J., watchmaker, gunsmith and soldier. In 1785 he turned his efforts to steamboats, though he made the surprising claim that he had never even heard of a steam engine. He tried, in his many experiments, the endless chain of paddles, the screw propeller, side wheels, stern wheel and stern paddles, but preferred above them all a suspended frame of oars invented by Henry Voight, a friend and co-worker. It is recorded that on July 27, 1786, he made a successful demonstration. In 1787 a company was formed in Philadelphia to exploit his invention, and in this year and in 1788 he built larger boats. The 1787 boat had 12 paddles, six on a side, and three on each side being at one time in the water. The passenger boat of 1789 has been generally pictured as having a set of stern paddles. In June, 1789, the company started regular freight and passenger service between Philadelphia, Burlington, Trenton and towns intermediate on the Delaware River. It is claimed that hundreds of passengers and many tons of freight were carried and that there was every prospect of continued success but for the wrecking of the "Perserverance" (a 25-ton schooner-rigged boat, to be used on the Mississippi) and the consequent crippling of the company so that it could not meet the competition of canal boats on the level stretches and flat banks of the Delaware.

In 1787 Fitch obtained a 14-year grant of exclusive rights to steam navigation in New York State. He was unable to use this great privilege, and it was transferred to Chancellor Livingston in 1798.

Fitch was sent by his company to France in 1791 seeking capital, and the introduction of the boat on French waters, but he was unsuccessful and a year later worked his way back to America having deposited his plans with an American consul. It is interesting to note that after his death these papers were made accessible to Robert Fulton.

Fitch's efforts to secure backing were still unsuccessful after his return to America. In 1796 he worked under the direct patronage of Chancellor Livingston and fitted up a little 18-ft. yawl with a boiler, engine and screw propeller. The

*The life and works of Robert Fulton are herein noted only as they touched the work of the other experimenters. For a fuller account see Engineering News, Sept. 16, 1909.

boiler was a ten-gallon kettle with a plank lid; the engine had a wooden cylinder. The propeller was been pictured as a helical blade of three complete turns, run half submerged. This yawl was tried on the famous old Collect Pond in New York City, but the experiment seems not to have satisfied the promoter and Fitch dropped his projects in disappointment. His health failed and in 1798 he died—some say a suicide.

No evidence has been found that Fitch ever actually employed hydraulic-jet propulsion, but in his petition for a patent (made in 1790 and granted in 1791) he claimed the exclusive right

> to apply steam to a trunk or trunks for drawing in water at the bow and forcing it out at the stern, for forcing air through a trunk or trunks by steam, for forcing air out at the stern and for applying the force of steam to cranks and paddles.

There seems to have been no direct commercial application of Fitch's invention, though many later inventors were influenced by his work. We have noted Fulton's scrutiny of Fitch's paper's, at Livingston's direction, when the latter was Minister to France.

Nathan Read, of Salem, Mass., knowing about the unsuccessful experiments of Rumsey and Fitch sought to overcome their difficulties by improving their machinery. In 1791 he patented a multi-tubular boiler with 78 vertical tubes, and a boat driven by a "chain pump"—probably an endless chain of paddles. In his first petition for these patents he claimed the invention of a boat with his boiler, with an improved Watt engine and with paddle-wheels. But he withdrew his claim to the invention of paddle-wheels on reading about previous experiments with wheels and oars. He built no practical boat, so far as can be ascertained.

One of Fitch's predecessors, who seems to have become informally associated with him and whose whole work was probably of minor consequence, was William Henry, of Lancaster, Pa. He is reputed to have been a gunsmith, but the records of the old American Philosophical Society show that he was active in the early organization of that society and was an investigator and writer on scientific topics generally. It is said that he made several studies on steam propulsion of boats during a trip to England in 1760, and there are a few Pennsylvania documents reported which record his trying such a boat in 1763 on the Conestoga River. In 1785 he met Fitch and joined efforts with him, as did several others. Henry died in 1789.

John Stevens, of Hoboken, N. J., had his interest in the problems of steam navigation aroused in 1787, perhaps from seeing Fitch's boat on the Delaware River, and he worked continually from that time until after Fulton's complete success was apparent. In 1792 he patented a boat with Savary pumps and propelled by a hydraulic jet.

In 1798 he associated with him Chancellor Livingston, Nicholas Roosevelt and Isambard Brunel, the famous English engineer who was then living in the United States and had just begun his engineering work. The four partners built a 30-ton boat after Stevens' patent, for trial on the Passaic River in New Jersey. There are vague references to a boat designed by these men, which was tried in 1800 in an attempt to secure the unutilized monopoly which the New York Legislature had granted to Fitch. But the boats failed to make the speed believed necessary (four miles per hour) and the project became dormant.

From 1801 to 1806 Stevens built boats with screw propellers which made speeds of from four to eight miles per hour. These boats had the water-tube boilers which he developed from Rumsey's "steam worm" and which he patented in 1791 and 1803. Various rotary and geared reciprocating high-pressure engines were made, but finally, when his boiler blew up, he was satisfied that there were neither workmen nor tools in America to do the high grade of work demanded by his designs. He accordingly reverted to paddle-wheel boats, with low-pressure engines and boilers, as being rough and ready and more practical.

In 1807, only a few days later than the famous trial of the "Clermont," John Stevens and his son Robert ran their "Phoenix" to Albany and back. His work again was ineffectual, as his former associate and brother-in-law, Livingston, had secured the rights of the Fitch monopoly grant and the Livingston-Fulton compact was in force—having been formed in October, 1802. We should note here that at this time New York State claimed rights over the Hudson River up to the New Jersey shores and New Jersey had not successfully contested the claim. Thus the success of the "Clermont" crowded Stevens out of this locality and the "Phoenix" was sent to Delaware Bay, making the trip under its own steam.

Stevens has been credited with building, in 1826, the first American steam locomotive running on rails. His business activity was no less marked than his engineering work. His petition to Congress for federal patent laws has been called the most effective of the several demands made at the time (1790). He advocated steam carriage over land as preferable to canal transportation as early as 1812, and in 1823 he secured a charter for the first Pennsylvania Railroad. The charter, however, was repealed in 1826, and it had no connection with the organization of the present Pennsylvania Railroad which was chartered in 1846. He developed Hoboken by an extensive real-estate project, and to further this he organized a New York and Hoboken ferry company. The first boat was started in 1817, in defiance to the Fulton-Livingston monopoly, a year before the Fulton ferry to Brooklyn was opened.

The name of Nicholas J. Roosevelt appears prominently in connection with those of Stevens, Livingston and Fulton. It appears that he also secured a patent on the use of side paddle-wheels, in Dec., 1814, basing his claim on experiments made in 1781 and '82 with a spring-driven model. For a while (1816) he engaged counsel and proclaimed his rights, but was later led to declare that his work was devoid of practical results and that credit for the evolution of the successful paddle-wheel was Fulton's. The only reasons advanced for this declaration are inferential and drawn from his connection with the Fulton-Livingston monopoly. For some time, about 1811, he was engaged in placing boats in service for them on the Mississippi River.

Oliver Evans is usually mentioned as one of the important pioneers. The records show that after much experimenting with high-pressure engines he built (1804) his "Erukter Amphibolos" or "Amphibious Digger." This was a flat-bottomed craft, 30 ft. long, weighing 18 tons. It was built and equipped some miles inland, wooden wheels were temporarily fitted, the engine was connected to one axle and the boat propelled itself to the water's edge for launching. The engine cylinder had a diameter of only 5 ins., for a stroke of 19 ins., in comparison with the diameter of 9 to 12 ins. then in vogue. This boat carried a chain of buckets for dredging, hooks for pulling snags and was propelled by a stern wheel. The only survival of Evans' projects seem to be found in the attempts of his heirs to secure the general adoption of his engines, about 1815.

A pioneer inventor whose steamboat projects rank in importance with those of Rumsey, Fitch and Stevens was Samuel Morey, of Orford, N. H., and Fairlee, Vt. He was a persistent experimenter, and a man of great inventive genius, who kept the first director of the patent office busy. Morey, it is said, owned a large area of timber land in Vermont which yielded him considerable sums, all of which he spent in a lifetime of experimenting. Aside from his steamboat projects, his chief work was with the combustion of oils and tars in presence of steam. Indeed he noted the explosive nature of mixtures of air and the vapors of volatile liquids like turpentine and alcohol, and in 1826 he proposed a design of explosion engine. He worked from 1814 to the end of his life (1843) to overcome the practical difficulties of such an engine which he believed would supersede the combination of steam boiler and cylinder. But we now can see that in all his work he was looking in a wrong direction. He did not directly use the force of the explosion but caused it to blow air out of the cylinder and by the condensation of the hot gases and vapor, replacing the air, he brought only atmospheric pressure into play. His explosion engine bears the same relation to modern internal-combustion motors as did Savary's and Newcomen's steam engines to those of to-day.

His first steamboat, a small one with a bow paddle-wheel, was built in 1793 and ran on the Connecticut River between Orford, N. H., and Fairlee, Vt. A second boat was built in New York about 1794 with a stern wheel, and was run from New York to Hartford, Conn. This boat was examined by Chancellor Livingston, and as a result Morey worked for a while under his patronage. Morey was offered $7,000 for the rights of his inventions on and about the Hudson, but he refused it, holding the sum insufficient.

In 1797, Morey built a third boat, at Bordentown, N. J., having side wheels on a transverse shaft at the center of which was a crank, essentially the same arrangement in use to-day. These combinations were all covered by general patents. In many old papers Morey is credited with having worked out a prototype of the present walking-beam which he did not patent. A similar mechanism was patented by one Dodd in 1811 and 1812.

After the trials of the Bordentown boat, a few Philadelphia citizens organized to develop Morey's design for commercial use, but financial troubles intervened and the plan was abandoned. Morey's principal backer in this move was a Doctor Allison, whose name has crept by chance into some accounts as an independent steamboat builder.

A prominent figure in the fights against the Fulton-Livingston steamboat monopoly was John Langton Sullivan, son of a Massachusetts governor and himself a "civil engineer." He received a patent for steamboats used as towboats, in 1814, over the protests of Fulton. In 1815 Samuel Morey invented a curious rotary engine for Langton's boats and through this connection Sullivan acquired many of Morey's rights. On these he based his efforts to break the New York monopoly. A boat equipped with Morey's rotary engine ran for a short time as a tug on the Santee River, and indeed made the long trip down the Atlantic coast from Boston to South Carolina under her own motive power. This unique engine seems to have been the original of the many designs made since, with revolving radial cylinders and a fixed crank pin.

As would be expected there were many sporadic attempts to make a serviceable steamboat with various and curious propulsion. For the most part these are neglected in this study. The Earl of Stanhope (with whom Fulton was in some way connected while studying civil engineering in England) in 1790 patented a steamboat with duck-foot paddles under the stern quarter. In 1792, two residents of Providence, R. I., built a similar curiosity. These men were Elijah Ormsbee and David Wilkinson, Ormsbee producing the hull and wooden parts while Wilkinson made the engine and metal fittings. Side wheels were tried, it was reported, and abandoned for "goose feet"—side paddles at the stern quarter. These paddles had a fore and aft motion, folding together on the forward stroke and opening to a width of 18 to 22 ins. The pressure of steam was used to raise the piston of the engine and by condensing the vapor, atmospheric pressure and the weight of the piston gave a power stroke. There is no record of commercial results, although the boat was successfully run.

Robert Fulton's commercial success in this country was duplicated abroad by that of Henry Bell, of Helensburgh, formerly a carpenter in Glasgow, who succeeded to the projects of Symington, and worked from 1808 on. It is said that Bell and Fulton were correspondents. In 1812, Bell's "Comet," a 25-ton, 3-HP. boat, as famous in Europe as the "Clermont" was in America, was run on the Clyde. As its arrangement was not patented, its success stimulated competition and similar craft were soon seen on many rivers.

The effect of the Fitch-Livingston-Fulton monopoly of steam navigation in New York State is seen all through any history we may write of the steamboat in America. It is pertinent, therefore, to consider the rights bestowed and the reasons for their importance. In 1787 Fitch obtained his grant from the state legislature for 14 years. The rights were transferred by the legislature to Chancellor Livingston in 1798, but with the condition that within a year he should build a boat which should go at a speed of four miles per hour and that he should not omit, for a year, having a boat plying the Hudson between New York City and Albany. In 1799, N. J. Roosevelt, one of Livingston's partners, secured an extension of the grant for 20 years from that year, conditional to producing the boat in two years. This lapsed by default, but in 1803 these privileges were extended to Fulton and Livingston for 20 years with a proof period of two years. In 1807 the proof period was extended for two years more.

By the provisions of the grant, no other persons were allowed to operate boats by steam power within the jurisdiction of the state. Inventors were not allowed even to use arrangements different from Fulton's. The Hudson valley at that time was one of the few great traffic ways to the interior, and it was wholly in the control of the State of New York. Canalization was impossible, on account of the steep banks of the river, and traffic was carried by slow and uncertain sailboats or by expensive animal carriage. The demand for cheap, swift and reliable transportation was great. On other inland ways like the Delaware River, canalization was possible, and self-propelled boats were not in demand until their cost should be low and their speeds much greater than by towed barges.

Any history of American steamboats shows that the patents issued in the early years of the federal statutes, often duplicated and overlapped. Because several men held patents covering the same ground each charged the other with various offenses, the justice of which charges we are unable to discern to-day.

In granting these first patents, no examinations were made. The inventor made his claim in a "declaration" and explained it in his "specifications." The claims showed the originality of the methods or devices and the explanations seem to have contained any pertinent matter desired. The validity of the patents and the scope of the claims were questions for the courts. From the beginning of such litigation, judges have recognized that it was the last step that counted, and that the man who obtained useful results was to be favored. The environment of an inventor, then, affected the validity of his claims. Whether or not he had funds and shop facilities often determined whether or not he could secure results which would be adjudged useful by the courts.

The benefits of fame and wealth which were sought by all these pioneers were finally reaped by Robert Fulton, who attained commercial success where others had failed, as a result of his ability as an engineer, promoter and organizer rather than as a pioneer inventor. It would, detract nothing from his fame, however, if due credit and honor were, even after the lapse of a century, awarded to those other pioneers who labored for the advancement by the art of steam navigation as earnestly as did Fulton and who reaped nothing but disappointment and loss, where he gained wealth and immortal fame.

LETTERS TO THE EDITOR.

Some Deductions from Marburg's I-Beam Tests.

Sir: In the issue of the Engineering News for Aug. 12, 1909, there appears an abstract of the paper read by Professor Edgar Marburg before the American Society for Testing Materials, in which he describes some interesting experiments on standard and wide-flanged I-beams. The tests show, apparently, a startlingly low value of the elastic limit for beams subjected to transverse loads. These values of elastic limit are obtained by finding the extreme fiber stress due to bending, at the load for which the load-deflection diagram ceases to be a straight line. The true value of the maximum fiber stress is slightly higher than appears from the discussion, for in that computation no account is taken of the shearing stress on the section of the beam.

MAXIMUM COMBINED STRESS NOT AT EDGE.—In the case of the 30-in. girder beam "G 31," for example, the intensity of the shearing stress is considerable. The depth of the beam is 30 ins. and the span 20 ft., so that the ratio of the depth to span is 1:8. Taking the load as given, 190,000 lbs. [95,000 lbs. at each quarter-point], and adding the weight of the beam, the total shear at the quarter-point is about 95,870 lbs., and the intensity of shearing stress at the root of the web, 1.72 ins. above the bottom fiber, is 4,260 lbs. per sq. in. At this point under the same loading the direct stress due to bending is 11,100 lbs. per sq. in. on the extreme fiber, or 9,820 lbs. per sq. in. at the root of the web. Combining these two stresses, the shearing stress of 4,260 lbs. per sq. in. and the direct tensile stress of 9,820 lbs. per sq. in., we find that the principal stresses at the root of the web are (1) a tensile stress of 11,400

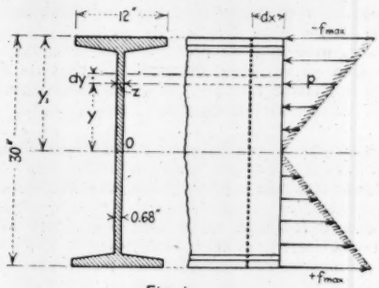


Fig. 1.

lbs. per sq. in. inclined about 20½° with the horizontal, and (2) a compressive stress of 1,600 lbs. per sq. in. acting at right angles to the first. The latter is, of course, of no importance. The former is but slightly higher than the value of 11,100 lbs. per sq. in. found for the extreme fiber stress; it is of interest, however, as showing that the greatest intensity of stress on the section of the beam occurs at a point slightly above the bottom of the beam, and not at the extreme fiber. It is further worthy of note that the tensile tests on specimens cut from the beams seem to indicate a poor quality of metal at this point of greatest intensity of stress.

COMPUTING THE MODULUS OF ELASTICITY FROM DEFLECTIONS.—Another point to which attention should be called is the value given for E, the modulus of elasticity in bending. The value given on p. 170 for Beam G 31 is 25,200,000 lbs. per sq. in. Professor Marburg states that although this is lower than the value determined by the direct tensile tests, it is in accordance with results obtained by other investigators along this line.

Such a low value of the modulus is hardly in accord, however, with the known properties of steel, and may be readily explained by reference to the effect of the shearing stresses in causing deflection of the beam. In the discussion of the tests the value of E is computed directly from the observed deflections, and it is assumed that all the deflection of the beam is the result of bending stress. As a matter of fact, however, the shearing

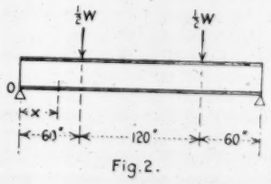


Fig. 2.

stresses play an important part in the deflection of a beam having such a large ratio (1:8) of depth to span. In order to get the true value of the modulus, the total deflection must be separated into two parts, that due to shear and that due to bending. By considering the internal work done on the beam by the shearing and bending stresses separately and equating their sum to the external work done on the beam by the deflecting forces (loads), an expression is obtained involving two unknowns, the tensile modulus of elasticity, E, and the shearing (or "transverse") modulus, C. By assuming C a definite fraction of E the equation may be solved for E.

This computation is based upon the method outlined in Greene's "Structural Mechanics," pp. 104 and 105, and may be summarized as follows:

(1) WORK OF BENDING.—Consider in Fig. 1 the work done by the bending stresses on a portion of the beam included between two right sections dx apart. At any point in the depth of the beam, p is the intensity of direct stress, and $p\,z\,dy$ = the total force on the element at that point. The strain (change in length) of the element under this force is $p\,dx/E$, and the work done by the stress is $\frac{1}{2} - p\,z\,dy\,p\,dx/E$, or $\frac{p^2}{2E} z\,dx\,dy$.

Integrating this expression with respect to y between the limits $(-y_1)$ and $(+y_1)$ will give the work done by the stresses due to bending on a length of beam dx. Expressing p in the terms of the bending moment M, this value is

$$\int_{-y_1}^{+y_1} \frac{p^2}{2E} z\,dx\,dy = \frac{M^2\,dx}{2EI^2} \int_{-y_1}^{+y_1} y^2 z\,dy$$

The quantity under the integral $= I$, hence the work done on the length dx is

$$\frac{M^2\,dx}{2EI}$$

The total work done on the beam by the stresses due to bending will be found by integrating the above expression throughout the length of the beam, noting that (see Fig. 2) $M = 1/2\ Wx$ from $x = 0$ to $x = 60$ ins. and from $x = 180$ ins. to $x = 240$ ins. (origin at left support), and that $M = 30\ W$ from $x = 60$ ins. to $x = 180$ ins. The total work due to bending then is equal to

$$2\int_0^{60} \frac{W^2 x^2}{8EI}\,dx + \int_{60}^{180} \frac{900\ W^2}{2EI}\,dx$$

$$= \frac{72{,}000\ W^2}{EI} = \frac{9.12\ W^2}{E} \quad (\text{for } I = 7894 \text{ in.}^4)$$

(2) WORK OF SHEAR.—The intensity of shearing stress at any point on the section of beam being called q, (see shear curve in Fig. 3), the shear acting on the elementary volume $x\,dx\,dy$ is $q\,x\,dy$ (Fig. 3) and the work done by this force is $\frac{1}{2} - q\,x\,dy - dx$, or $\frac{q}{C} - \frac{q^2 x}{2C} dx\,dy$, C being the shearing modulus of elasticity, or the shearing stress divided by the angular distortion caused by it.

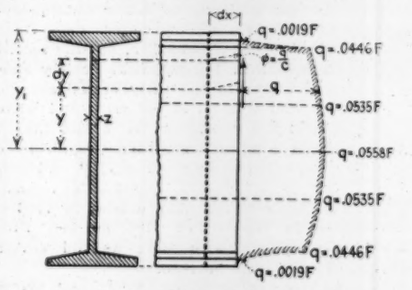


Fig. 3.

The work done on a portion of the beam included between two sections dx apart will then be

$$\int_{-y_1}^{+y_1} \frac{q\,z}{2C} dx\,dy = \frac{dx}{2C} \int_{-y_1}^{+y_1} q^2 z\,dy = \frac{Q}{2C} dx,$$

if we represent by Q the value of the expression under the integral. The solution of this integral is readily effected by graphical means from the curve of shearing stress. It is found to be, in terms of total shear F,

$$Q = .0501\ F^2 \text{ approximately.}$$

To get the total work done by the shearing stresses, integrate $\frac{Q}{2C} dx$ throughout the length of the beam, noting that only the end quarters of the span (or one-half the total length) are affected by shear, and on these end portions the total shear at any section is $F = 1/2\ W$. The total internal work due to shear is

$$2\int_0^{60} \frac{Q}{2C} dx = \frac{1}{C} \int_0^{60} Q\,dx$$

$$= \frac{.0501\ F^2}{C} \times \int_0^{60} dx = \frac{60 \times .0501}{C} \times \frac{W^2}{4}$$

$$= 0.7515\ W^2 / C$$

If the value of G, the shearing modulus, is assumed to be 5/13 (or 38.5%) of E, corresponding to the value of 3/10 for Poisson's ratio,* the above becomes

$$\frac{0.7515\ W^2}{.385\ E} = 1.95 \frac{W^2}{E}$$

*Hütte, Ingenieurs Taschenbuch, 19th Ed'n, I, p. 83.

...s we have

...nternal work due to *bending* stresses, $9.12 \frac{W^2}{E}$ (82% of ...otal)

...nternal work due to *shearing* stresses, $1.95 \frac{W^2}{E}$ (18% of ...otal).

The work done on the beam by the external forces ...oads) will be $2\ (\frac{1}{2}\ W.\ \frac{1}{2}\ \delta) = \frac{W\delta}{2}$, δ being the amount ...f the deflection of the beam under one of the loads. This actual deflection of the beam at one of the load points was not directly observed; it may, however, be approximately deduced from the observed maximum deflection, which was 0.165-in. for a load of 165,000 lbs., these being the data from which the above-mentioned value of 25,200,000 lbs. per sq. in. for E was computed. In Fig. 4 the deflection of the beam at any point is shown to be made up of two parts, that due to shear, represented by the ordinate to the broken line $A\ C\ D\ B$, and that due to bending, represented by the ordinate to the curve $A\ E\ B$. At the load point, C, the deflection $\delta = C\ F = \delta_s + \delta_b$. Of these $\delta_b = \frac{8}{11}$ of $G\ E$, while δ_s may be found by assuming a constant intensity of shear on the web, equal to, say, 0.051 F. The shear on the flanges, being relatively small, may be neglected without serious error. The distortion due to shear, in a length dx, is then (Fig. 3)

$$\phi\ dx = \frac{q\ dx}{C} = \frac{.051\ F}{C}\ dx = .000366\ dx$$

for values of $F = 82{,}500$ lbs. and $C = 11{,}500{,}000$ lbs. per sq. in. Integrating this betwen the limits $x = 0$ and $x = 60$ ins.,

$$.000366 \int_0^{60} dx = .022 \text{ in.}$$

as the deflection due to shear alone. The deflection at the center due to bending alone will be, therefore, 0.143 in., and at the load point the deflection due to bending will be 8/11 of the maximum deflection due to bending, or 0.104 in., hence the total deflection under the load is $\delta = 0.126$ in. The work done by the external forces is, then, $0.063\ W$ and this must equal the total internal work, or $11.07 \frac{W^2}{E} = .063\ W$.

Whence $E = 29{,}000{,}000$ lbs. per sq. in.

EFFECT OF NON-VERTICALITY.—A further point of interest in connection with beams of considerable depth, although not directly connected with the tests under discussion, is the effect of a slight tilting of the beam on the extreme-fiber stresses, the loads being assumed to remain vertical. In the case of beam G 31 (a 30-in. 175-lb. I-beam) the extreme-fiber stress will be found by dividing the bending moment by the section modulus only in case the plane of loads, M, coincides with the major principal axis of the section; *i. e.*, under vertical loads, Fig. 5, the web of the beam must be vertical. If the loads remain vertical, but the web is tilted slightly, as in Fig. 6, the maximum stresses occur at the points a and b, and for a tilting of only 3° 10′ from the vertical, as shown in Fig. 6, these stresses become 50% greater than those for the condition of Fig. 5 under the same M. If the deviation is 6° 20′ from the vertical, as in Fig. 7, the extreme-fiber stresses (at a and b) are just double those for the condition shown in Fig. 5. A consideration of this point shows the importance of keeping the plane of the web strictly coincident with the plane of the external loads, if the greatest strength of the girder is to be utilized. The neutral axis, which is horizontal for the condition shown in Fig. 5, becomes inclined as the web is tilted out of the vertical; its position is shown in each case by the line n-n. The beam will bend, not in a vertical direction, but in a direction perpendicular to n-n.

C. J. Tilden.

Ann Arbor, Mich., Dec. 14, 1909.

Fig.5.

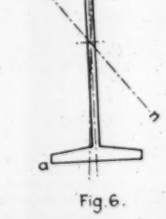


Fig.6.

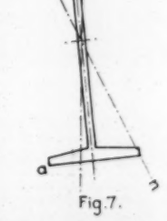


Fig.7.

[The above was submitted to Prof. Edgar Marburg for reply. He comments on Prof. Tilden's deductions as follows:]

Sir: Professor Tilden's critical analysis of certain data reported in connection with recent tests of steel I-beams is welcomed as an interesting and suggestive contribution to the subject.

That the principal tensile stress at the root of the lower flange in the particular beam under review should possess, theoretically, an intensity nearly 3% greater than that in the extreme fiber, is of practical significance, first, in that it directs attention to a condition tending to place a fairly definite limit on the minimum allowable web thickness, apart from the usual considerations of shearing and buckling strength and requirements in rolling; and second, in that it suggests an element that should be duly reckoned with in the case of beams of exceptionally short span. The degree of refinement to which computations of stresses in rolled beams may consistently be carried, depends largely on the magnitude and range of the stresses inherent in such members from the combined effect of the dragging action in rolling and unequal shrinkage in cooling. The existence of considerable internal stress in the finished product, especially in the vicinity of the root of the flange, is hardly to be doubted. In the judgment of the writer, this is one of the most important questions awaiting definite experimental determination. By subdividing a short beam into narrow strips and accurately measuring their lengths between fixed gage-points before and after separation from the beam, the conditions of internal stress would be revealed within closely approximate limits. Strips shortening on their release from the surrounding material could be restored to their original length in the testing machine, and the previously existing internal stress could thus be determined without dependence on an assumed value of the modulus of elasticity.

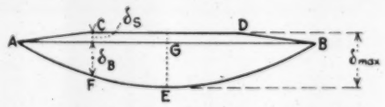


Fig.4.

As indicative of the variable behavior of the material in the flanges of the same beam, due to initial stresses, inferior material, or whatever causes, it need only be stated that in the particular beam under consideration the elastic limits of the tensile and compressive flanges by direct extensometer measurements were found to be 11,700 and 18,600 lbs. per sq. in., respectively, and that similar discrepancies, although in no instance of like relative magnitude, were noted in many other beams. The elastic limits referred to here are the extreme-fiber stresses computed from the load beyond which the load-fiber-deformation ratio ceased to remain constant. The elastic limits, computed by a second and wholly independent method, namely as the products of the unit deformation up to the elastic limit and the modulus of elasticity in pure tension of a specimen cut from the flange, were 11,700 and 19,000 lbs. per sq. in., respectively, the former agreeing exactly, and the latter within 2%, with the values deduced by the first method. Again, the former value is seen to be substantially in agreement with the elastic limit of 11,100 lbs. per sq. in., quoted by Professor Tilden, computed from the load beyond which the load-deflection ratio ceased to remain constant, whereas the latter is over 70% higher.

According to Professor Tilden's computations relative to the modulus of elasticity in bending by taking account of the work of shear, the modulus becomes 29,000,000 instead of 25,200,000, as reported on the basis of the method commonly employed in practice, representing an increase of about 15%. While it is true that the resulting value is thus brought practically in accord with that in pure tension for this particular beam, this circumstance hardly serves to prove that the added refinements of this theoretically correct method are really justified. Had this method been applied, for example, to Beam B28, of like depth and span, for which the reported modulus is 29,400,000, an assumed equal percentage of increase would have led to the value 33,800,000 lbs. per sq. in., which, in comparison with the modulus in pure tension, is as much too high as the modulus reported for beam G31 is seemingly too low.

The element of shear in the computed values of the moduli in bending, was designedly omitted, and that procedure is believed to be justified, not only on the ground that it accords with the method commonly followed in practice, but because the apparently greater accuracy of the more refined method is believed to be largely fictitious. Compared with its determination in pure tension, the modulus of elasticity deduced from bending is at best only an approximation. In the case of beams of relatively short spans, if a modulus in bending 10 to 15% lower than in tension be used in connection with the ordinary formulas for deflection, the resulting values will probably prove as reliable, on the average, as those by the refined method employed by Professor Tilden. For extremely short spans, where the influence of the shear on the deflection cannot be neglected without considerable error, it is sufficient for all practical purposes to assume the shear as borne wholly by the web, and uniformly distributed over the latter. However, the value of the deflection under such circumstances is rarely of importance from a practical standpoint.

To illustrate the slight error involved in the assumptions regarding shear here recommended, let the same be applied to the case analyzed by Professor Tilden. The sectional area of the web is approximately 18 sq. ins. Hence Q becomes equal to $0.0556\ F^2$, instead of $0.0501\ F^2$, or about 10% greater. This leads to the value $2.16\ W^2/E$ in place of $1.95\ W^2/E$ for the internal work due to shearing stresses, which means that it becomes now 19% of the total work instead of 18% as by Professor Tilden's analysis. The resulting final equation is $11.28\ W^2/E = 0.063\ W$, whence for $W = 165{,}000$ lbs. $E = 29{,}500{,}000$, a value less than 2% greater than by the refined and laborious method adopted by Professor Tilden.

In support of the view that ultra-refinements are out of place in such calculations, the results of certain tests made in the laboratory of the University of Pennsylvania may be briefly cited:

A 7-in. 15-lb. I-beam was tested under central loading on spans of 8 and 3½ ft. By the ordinary formula for deflection, neglecting shears, the resulting moduli were about 26,000,000 and 16,000,000 respectively. By substituting the observed deflections for each span in the formula:

$$\delta = \frac{Wl^3}{48\ EI} + \frac{Wl}{4\ Cn}$$

and solving the two equations simultaneously for E and C, the resulting values are 30,700,000 and 5,370,000 respectively, the ratio of the latter to the former being 0.175 instead of 0.385, as assumed by Professor Tilden on the basis of 0.3 for Poisson's ratio. The above formula obviously implies the assumption of uniform distribution of shear over the sectional area of the web.

The relation between the deflection due to shear and that due to direct stress, as expressed by the ratio of the second to the first term in the second member of the above formula, may be reduced to the simple form $5\ K/k^2$, in which K is the ratio of the entire sectional area of the beam to that of the web, and k is the ratio of span to depth of beam. This result is based on the value of 0.385E for C, assumed by Professor Tilden, and also involves the assumption that the radius of gyration of the section, with reference to the principal neutral axis, is equal to 4/10 of the depth of the beam, which is a close approximation, especially for beams of the lightest section for any given depth. The value of K will be found to vary between limits of about 2.1 and 3.1.

Edgar Marburg.

University of Pennsylvania.
Philadelphia, Pa.,
Feb. 7, 1910.

A Table of Moments of Inertia of Flat Rectangles.

Sir: The handbook entitled "Steel in Construction," published formerly by the Pencoyd Iron Works (but now out of print), contained a table of moments of inertia of rectangles about an axis perpendicular to the long side. The moments were given for rectangles varying in size from 6 × ¼ ins. to 40 × ¾ in. This table will also be found in the handbook issued by the Carnegie Steel Co. In the Cambria Iron Co.'s handbook will be found values of moments of inertia of rectangles from 2 × ¼-in. in size up to 60 × 1 in. These tables are time-savers in figuring moments of inertia of built-up sections such as plate-girders and columns, or of a combination of I-beams and plates.

But none of these handbooks contains a table of moments of inertia of rectangles about an axis *parallel* to the long side. In Sample's "Properties of Steel Sections," one will find a table of this kind for rectangles from 4 × ¼-in. in size up to 60 × 1-in. The accompanying table gives such moments of inertia for rectangles from 6 × ¼-in. up to 40 × 3 ins. This is more complete as regards width of rectangle and may be useful in calculating moments of resistance of rectangular beams with the long side in a horizontal position. It is admitted, of course, that beams are rarely used in that position; nevertheless, cases may arise where these tables will be useful and save time in making calculations.

From the formula for the moment of inertia of a rectangle, $1/12\ bd^3$, it will be seen that where b is the

variable quantity, $\frac{d^2}{12}$ is the constant increment, and the successive values of the moment may be obtained by adding the value of $\frac{d^2}{12}$ to the preceding moment.

The table was compiled in this manner, and checked by computing the last figure in each row independently. The table was prepared in the fall of 1904, and, therefore, was in use by me long before Sample's book was published.

H. Loewenherz.

1376 Lexington Ave., New York City, Dec. 12, 1909.

A More Optimistic View of the Panama Canal's Future Traffic.

Sir: The letter of A. P. C. in your issue of Feb. 10 relative to the Panama Canal, is interesting, inasmuch as it shows the point of view from which at certain periods in a man's lifetime such undertakings are regarded.

I have been through the Suez Canal four times, the first time in 1875, when a young lad, and I have also seen the work done by the French on the Panama Canal prior to its purchase by the United States. There is no similarity whatever between the two canals as to the difficulty presented. Had the Panama topography, climatic conditions, etc., existed on the site of what is now the Suez Canal, it is much to be doubted if the latter would ever have been built.

There need be no apprehension as to the future of the Panama proposition. It will surely prove to be one of this country's most valuable assets, both in times of peace and of war. The results of the marine—American—traffic it will develop will surprise the most pessimistic. I have been on the South American west coast and it is surely suffering for the want of some healthy stimulus to aid in the development of its resources. For service between the east coast of the United States and the west coast of South America, Central America, Mexico, California, Oregon, Washington and Alaska, a new type of American freight vessel will no doubt be evolved in readiness for the opening of the canal.

We have the experience gained in freight-handling carriers on the Great Lakes, and no doubt a happy medium between the lake and ocean carrier, combining the economical and best points of both, will be arrived at.

It must be remembered that shipbuilding is not a lost art in this country; and when vessels to carry 6,000 to 10,000 tons are built on the Great Lakes (Lorain, Ohio) in from 90 to 100 days, what can be done on the Atlantic Coast should the demand warrant? I would not be surprised to see the future traffic of the Panama Canal discount that of the Suez and run a close second to the Sault Ste. Marie. The time has surely come now when we should have a short cut to the Pacific, and I ho it will be the direct means of helping to make our f known once more on the high seas.

G. H

New York, Feb. 12, 1910.

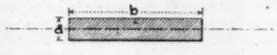
Concerning the Cost and Other Disadvantage of Rail Transfer at Panama.

Sir: In your issue of Feb. 10, 1910, appears a lett from "A. P. C." questioning the value of the Panam Canal, and giving as one of his objections that the co of handling freight at the Isthmus by rail, assumed a $3,000,000 per year, is less than half the interest o the cost of building the Canal, leaving out of considera tion the cost of maintenance of the Canal.

One of the things most desired by those who have mer chandise to be shipped to foreign ports is a reasonabl early delivery, or at least a definite time of delivery Supposing that a bill of goods is delivered at th Isthmus and quickly transported by rail across to th opposite side. How long, on the average, would th goods have to wait before another vessel having th desired port as a destination would appear at the Isth mus to take freight? The impossibility of making an sort of a guaranty that goods would be handled in reasonable time is the one feature that has heretofor made shipment of freight via Panama an unsatisfactory

Moments of Inertia of Flat Rectangles.

(Computed by H. Loewenherz.)



Width b in ins.	Thickness d in inches. ¼-in.	5/16-in.	⅜-in.	7/16-in.	½-in.	9/16-in.	⅝-in.	11/16-in.	¾-in.	13/16-in.	⅞-in.	15/16-in.	Width b in ins.	1-in.	1 1/16-in.	1¼-in.	1 3/16-in.	1¼-in.	1 5/16-in.	1⅜-in.	1 7/16-in.	1½-in.	1 9/16-in.	2⅛-in.	1 11/16-in.	Width b in ins.
6	.008	.015	.026	.042	.062	.089	.122	.162	.211	.268	.335	.412	6	0.50	0.60	.71	.84	.98	1.13	1.30	1.48	1.69	1.91	2.14	2.40	6
7	.009	.018	.031	.049	.073	.104	.142	.189	.246	.313	.391	.481	7	.583	0.70	.83	.98	1.14	1.32	1.52	1.73	1.97	2.22	2.50	2.80	7
8	.010	.020	.035	.056	.083	.119	.163	.217	.281	.358	.447	.549	8	.667	0.80	.95	1.12	1.30	1.51	1.73	1.98	2.25	2.54	2.86	3.20	8
9	.012	.023	.039	.063	.094	.133	.183	.244	.316	.402	.502	.618	9	.75	0.90	1.07	1.26	1.46	1.70	1.95	2.23	2.53	2.86	3.22	3.60	9
10	.013	.025	.044	.070	.104	.148	.203	.271	.352	.447	.558	.687	10	.833	1.00	1.19	1.39	1.63	1.88	2.17	2.47	2.81	3.18	3.57	4.00	10
11	.014	.028	.048	.077	.115	.163	.224	.298	.387	.492	.614	.755	11	.917	1.10	1.30	1.53	1.79	2.07	2.38	2.72	3.09	3.50	3.93	4.40	11
12	.016	.030	.053	.084	.125	.178	.244	.325	.422	.536	.670	.824	12	1.00	1.20	1.42	1.67	1.95	2.26	2.60	2.97	3.37	3.81	4.29	4.80	12
13	.017	.033	.057	.091	.135	.193	.264	.352	.457	.581	.726	.893	13	1.083	1.30	1.54	1.81	2.11	2.45	2.82	3.22	3.66	4.13	4.65	5.20	13
14	.018	.036	.061	.098	.146	.208	.285	.379	.492	.626	.782	.961	14	1.167	1.40	1.66	1.95	2.28	2.64	3.03	3.46	3.94	4.45	5.01	5.61	14
15	.019	.038	.066	.105	.156	.222	.305	.406	.527	.670	.837	1.030	15	1.25	1.50	1.78	2.09	2.44	2.83	3.25	3.71	4.22	4.77	5.36	6.01	15
16	.021	.041	.070	.112	.167	.237	.325	.433	.562	.715	.893	1.099	16	1.333	1.60	1.90	2.23	2.60	3.01	3.47	3.96	4.50	5.08	5.72	6.41	16
17	.022	.043	.075	.119	.177	.252	.346	.460	.598	.760	.949	1.167	17	1.417	1.70	2.02	2.37	2.77	3.20	3.68	4.21	4.78	5.40	6.08	6.81	17
18	.023	.046	.079	.126	.187	.267	.366	.487	.633	.805	1.005	1.236	18	1.50	1.80	2.13	2.51	2.93	3.39	3.90	4.45	5.06	5.72	6.44	7.21	18
19	.025	.048	.083	.133	.198	.282	.387	.514	.668	.849	1.061	1.305	19	1.583	1.90	2.25	2.65	3.09	3.58	4.11	4.70	5.34	6.04	6.79	7.61	19
20	.026	.051	.088	.140	.208	.297	.407	.542	.703	.894	1.116	1.373	20	1.667	2.00	2.37	2.79	3.25	3.77	4.33	4.95	5.62	6.36	7.15	8.01	20
21	.027	.053	.092	.146	.219	.311	.427	.569	.738	.939	1.172	1.442	21	1.750	2.10	2.49	2.93	3.42	3.96	4.55	5.20	5.91	6.67	7.51	8.41	21
22	.029	.056	.097	.153	.229	.326	.448	.596	.773	.983	1.228	1.511	22	1.833	2.20	2.61	3.07	3.58	4.14	4.76	5.44	6.19	6.99	7.87	8.81	22
23	.030	.058	.101	.160	.240	.341	.468	.623	.809	1.028	1.284	1.579	23	1.917	2.30	2.73	3.21	3.74	4.33	4.98	5.69	6.47	7.31	8.22	9.21	23
24	.031	.061	.105	.167	.250	.356	.488	.650	.844	1.073	1.340	1.648	24	2.000	2.40	2.85	3.35	3.91	4.52	5.20	5.94	6.75	7.63	8.58	9.61	24
25	.032	.063	.110	.174	.260	.371	.509	.677	.879	1.117	1.396	1.717	25	2.083	2.50	2.97	3.49	4.07	4.71	5.41	6.19	7.03	7.95	8.94	10.01	25
26	.034	.066	.114	.181	.271	.386	.529	.704	.914	1.162	1.451	1.785	26	2.167	2.60	3.08	3.63	4.23	4.90	5.63	6.43	7.31	8.26	9.30	10.41	26
27	.035	.069	.119	.188	.281	.400	.549	.731	.949	1.207	1.507	1.854	27	2.25	2.70	3.20	3.77	4.39	5.09	5.85	6.68	7.59	8.58	9.65	10.81	27
28	.036	.071	.123	.195	.292	.415	.570	.758	.984	1.251	1.563	1.923	28	2.334	2.80	3.32	3.91	4.56	5.27	6.06	6.93	7.87	8.90	10.01	11.21	28
29	.038	.074	.127	.202	.302	.430	.590	.785	1.019	1.296	1.619	1.991	29	2.417	2.90	3.44	4.05	4.72	5.46	6.28	7.18	8.16	9.22	10.37	11.61	29
30	.039	.076	.132	.209	.312	.445	.610	.812	1.055	1.341	1.675	2.060	30	2,500	3.00	3.56	4.19	4.88	5.65	6.50	7.42	8.44	9.54	10.73	12.01	30
31	.040	.079	.136	.216	.323	.460	.631	.839	1.090	1.386	1.731	2.129	31	2,583	3.10	3.68	4.32	5.04	5.84	6.71	7.67	8.72	9.85	11.08	12.41	31
32	.042	.081	.141	.223	.333	.475	.651	.866	1.125	1.430	1.786	2.197	32	2.667	3.20	3.80	4.46	5.21	6.03	6.93	7.92	9.00	10.17	11.44	12.81	32
33	.043	.084	.145	.230	.344	.489	.671	.894	1.160	1.475	1.842	2.266	33	2.75	3.30	3.91	4.60	5.37	6.22	7.15	8.17	9.28	10.49	11.80	13.21	33
34	.044	.086	.149	.237	.354	.504	.692	.921	1.195	1.520	1.898	2.335	34	2.833	3.40	4.03	4.74	5.53	6.41	7.36	8.42	9.56	10.81	12.16	13.61	34
35	.045	.089	.154	.244	.365	.519	.712	.948	1.230	1.564	1.954	2.403	35	2.917	3.50	4.15	4.88	5.70	6.59	7.58	8.66	9.84	11.13	12.51	14.01	35
36	.047	.091	.158	.251	.375	.534	.732	.975	1.266	1.608	2.010	2.472	36	3.00	3.60	4.27	5.02	5.86	6.78	7.80	8.91	10.12	11.44	12.87	14.42	36
37	.048	.094	.163	.258	.385	.549	.753	1.002	1.301	1.654	2.066	2.541	37	3.083	3.70	4.39	5.16	6.02	6.97	8.01	9.16	10.41	11.76	13.23	14.82	37
38	.049	.097	.167	.265	.396	.564	.773	1.029	1.336	1.698	2.121	2.609	38	3.167	3.80	4.51	5.30	6.18	7.16	8.23	9.41	10.69	12.08	13.59	15.22	38
39	.051	.099	.171	.272	.406	.578	.793	1.056	1.371	1.743	2.177	2.678	39	3.25	3.90	4.63	5.44	6.35	7.35	8.45	9.65	10.97	12.40	13.94	15.62	39
40	.052	.102	.176	.279	.417	.593	.814	1.083	1.406	1.788	2.233	2.747	40	3.334	4.00	4.75	5.58	6.51	7.54	8.66	9.90	11.25	12.71	14.30	16.02	40

Width b in ins.	Thickness d in inches. 1¾-in.	1 13/16-in.	1⅞-in.	1 15/16-in.	2-inch.	2 1/16-in.	2⅛-in.	2 3/16-in.	2¼-in.	2 5/16-in.	2⅜-in.	2 7/16-in.	Width b in inches.	2½-in.	2 9/16-in.	2⅝-in.	2 11/16-in.	2¾-in.	2 13/16-in.	2⅞-in.	2 15/16-in.	3-inch.	Width b in inches.
6	2.68	2.98	3.29	3.64	4.00	4.39	4.80	5.23	5.69	6.18	6.70	7.24	6	7.81	8.41	9.04	9.70	10.40	11.12	11.88	12.67	13.50	6
7	3.13	3.47	3.84	4.24	4.67	5.12	5.60	6.11	6.64	7.21	7.81	8.45	7	9.11	9.81	10.55	11.32	12.13	12.98	13.86	14.78	15.75	7
8	3.57	3.97	4.39	4.85	5.33	5.85	6.40	6.98	7.59	8.24	8.93	9.65	8	10.42	11.22	12.06	12.94	13.86	14.83	15.84	16.90	18.00	8
9	4.02	4.46	4.94	5.45	6.00	6.58	7.20	7.85	8.54	9.27	10.05	10.86	9	11.72	12.62	13.56	14.56	15.60	16.68	17.82	19.01	20.25	9
10	4.47	4.96	5.49	6.06	6.67	7.31	7.99	8.72	9.49	10.30	11.16	12.07	10	13.02	14.02	15.07	16.17	17.33	18.54	19.80	21.12	22.50	10
11	4.91	5.46	6.04	6.67	7.33	8.04	8.80	9.59	10.44	11.33	12.28	13.27	11	14.32	15.42	16.58	17.79	19.06	20.39	21.78	23.23	24.75	11
12	5.36	5.95	6.59	7.27	8.00	8.77	9.59	10.47	11.39	12.37	13.39	14.48	12	15.62	16.83	18.09	19.41	20.80	22.25	23.76	25.35	27.00	12
13	5.80	6.45	7.14	7.88	8.67	9.50	10.39	11.34	12.34	13.40	14.51	15.69	13	16.93	18.23	19.59	21.03	22.53	24.10	25.74	27.46	29.25	13
14	6.25	6.95	7.69	8.48	9.33	10.23	11.19	12.21	13.29	14.43	15.63	16.89	14	18.23	19.63	21.10	22.64	24.26	25.95	27.72	29.57	31.50	14
15	6.70	7.44	8.24	9.09	10.00	10.97	11.99	13.08	14.24	15.46	16.74	18.10	15	19.53	21.03	22.61	24.26	25.99	27.81	29.70	31.68	33.75	15
16	7.14	7.94	8.79	9.70	10.67	11.70	12.79	13.96	15.19	16.49	17.86	19.31	16	20.83	22.43	24.12	25.88	27.73	29.66	31.68	33.79	36.00	16
17	7.59	8.43	9.34	10.30	11.33	12.43	13.59	14.83	16.14	17.52	18.98	20.51	17	22.13	23.84	25.62	27.50	29.46	31.52	33.66	35.91	38.25	17
18	8.04	8.93	9.89	10.91	12.00	13.16	14.39	15.70	17.08	18.55	20.10	21.72	18	23.44	25.24	27.13	29.11	31.19	33.37	35.64	38.02	40.50	18
19	8.48	9.43	10.44	11.51	12.67	13.89	15.19	16.57	18.03	19.58	21.21	22.93	19	24.74	26.64	28.64	30.73	32.93	35.22	37.62	40.13	42.75	19
20	8.93	9.92	10.99	12.12	13.33	14.62	15.99	17.45	18.98	20.61	22.33	24.14	20	26.04	28.04	30.15	32.35	34.66	37.08	39.61	42.24	45.00	20
21	9.38	10.42	11.53	12.73	14.00	15.35	16.79	18.32	19.93	21.64	23.44	25.34	21	27.34	29.45	31.65	33.97	36.39	38.93	41.59	44.36	47.25	21
22	9.82	10.92	12.08	13.33	14.67	16.08	17.59	19.19	20.88	22.67	24.56	26.55	22	28.64	30.85	33.16	35.58	38.13	40 78	43.57	46.47	49.50	22
23	10.27	11.41	12.63	13.94	15.33	16.82	18.39	20.06	21.83	23.70	25.67	27.76	23	29.95	32.25	34.67	37.20	39.86	42.64	45.55	48.58	51.75	23
24	10.72	11.91	13.18	14.55	16.00	17.55	19.19	20.93	22.78	24.73	26.79	28.96	24	31.25	33.65	36.17	38.82	41.59	44.49	47.53	50.69	54.00	24
25	11.16	12.40	13.73	15.15	16.67	18.28	19.99	21.81	23.73	25.76	27.91	30.17	25	32.55	35.05	37.68	40.44	43.32	46.35	49.51	52.80	56.25	25
26	11.61	12.90	14.28	15.76	17.33	19.01	20.79	22.68	24.68	26.79	29.02	31.38	26	33.85	36.46	39.19	42.05	45.06	48.20	51.49	54.92	58.50	26
27	12.06	13.40	14.83	16.36	18.00	19.74	21.59	23.55	25.63	27.82	30.14	32.58	27	35.15	37.86	40.69	43.67	46.79	50.05	53.47	57.03	60.75	27
28	12.50	13.89	15.38	16.97	18.67	20.47	22.39	24.42	26.58	28.85	31.25	33.79	28	36.46	39.26	42.20	45.29	48.52	51.91	55.45	59.14	63.00	28
29	12.95	14.39	15.93	17.58	19.33	21.20	23.19	25.30	27.53	29.88	32.37	35.00	29	37.76	40.66	43.71	46.91	50.26	53.76	57.43	61.25	65.25	29
30	13.40	14.89	16.48	18.18	20.00	21.93	23.99	26.17	28.48	30.91	33.49	36.20	30	39.06	42.07	45.22	48.52	51.99	55.62	59.41	63.37	67.50	30
31	13.84	15.38	17.03	18.79	20.67	22.66	24.79	27.04	29.42	31.94	34.60	37.41	31	40.36	43.47	46.73	50.14	53.72	57.47	61.39	65.48	69.75	31
32	14.29	15.88	17.58	19.39	21.33	23.40	25.59	27.91	30.37	32.98	35.72	38.62	32	41.66	44.87	48.23	51.76	55.46	59.32	63.37	67.59	72.00	32
33	14.74	16.37	18.13	20.00	22.00	24.13	26.39	28.78	31.32	34.01	36.84	39.82	33	42.97	46.27	49.74	53.38	57.19	61.18	65.35	69.70	74.25	33
34	15.18	16.87	18.68	20.61	22.67	24.86	27.19	29.66	32.27	35.04	37.95	41.03	34	44.27	47.67	51.25	54.99	58.92	63.03	67.33	71.81	76.50	34
35	15.63	17.37	19.22	21.21	23.33	25.59	27.99	30.53	33.22	36.07	39.07	42.24	35	45.57	49.08	52.75	56.61	60.65	64.89	69.31	73.93	78.75	35
36	16.08	17.86	19.77	21.82	24.00	26.32	28.79	31.40	34.17	37.10	40.19	43.44	36	46.87	50.48	54.26	58.23	62.39	66.74	71.29	76.04	81.00	36
37	16.52	18.36	20.32	22.42	24.67	27.05	29.59	32.27	35.12	38.13	41.30	44.65	37	48.17	51.88	55.77	59.85	64.12	68.59	73.27	78.15	83.25	37
38	16.97	18.85	20.87	23.03	25.33	27.78	30.39	33.15	36.07	39.16	42.42	45.86	38	49.48	53.28	57.28	61.46	65.85	70 45	75.25	80.26	85.50	38
39	17.42	19.35	21.42	23.64	26.00	28.51	31.18	34 02	37.02	40.19	43.53	47.06	39	50.78	54.68	58.78	63.08	67.59	72.30	77.23	82.37	87.75	39
40	17.86	19.85	21.97	24.24	26.67	29.24	31.98	34.89	37.97	41.22	44.65	48.27	40	52.08	56.09	60.29	64.70	69.32	74.16	79.21	84.49	90.00	40

xperiment. Shippers would rather consume the longer ime in shipping around the Horn, say from New York to Chilean ports, than to risk delay, breakage, damage by weather, and handling charges by shipment over the isthmus by rail. With the Canal in working order, all such freight will travel the short and safe route by way of the Isthmus.

R. W. Baily.

Des Moines, Iowa, Feb. 13, 1910.

More Concerning Electric Currents for Thawing Anchor Ice on Intake Screens.

Sir: Mr. Rudolph Hering's letter in your issue of Feb. 3 recalls discussion with Mr. George H. Benzenberg, Past President Am. Soc. C. E., about the use of electric current for clearing ice from intakes. Facts about increase of traction and light installations with the increase in quantity of water supplied to a city were noted. Also the excellent opportunity to divert traction currents in those hours of the night when few cars were in use. Questions about size of cables, methods of enameling wires to lessen danger of short circuit, while giving needful resistance and the degree of heat required were considered and other questions were referred to an electrical engineer.

The subject is too complex for a single paragraph. It is doubtful if strong electric currents would help greatly in a case like that mentioned by Mr. Lochridge. The flow of water through the intake would carry the heat into the supply, besides bringing more icy particles to the screen. The conditions would be excellent for the transfer of a large amount of energy with little positive advantage. The energy of Niagara converted into heat (as it is) adds less than two-tenths of a degree Fahrenheit to the temperature of the waters of Niagara. The cataract would need to be proportionately higher to change ice at 32° to water at 32°. This shows how trivial all station work becomes when compared with Nature's work outside on a cold night. It was a part of the proposed plan to discontinue the use of the intake and permit the heat to liberate the ice that it might rise to the surface.

The Toronto case is not clear. The slow velocity through the grating merits attention. Ice forms upon wooden piles and timber dams. In forests, floods leave high water marks if not the highest. Often in a few hours a thin sheet of ice freezes so firmly to tree trunks that as it breaks down, as the waters subside, it takes a part of the bark and leaves a mottled color band around the tree noticeable long afterward. The thin edge of a cedar shingle will support a heavy icicle when the temperature is but a trifle below freezing.

Many metals are good conductors, but they convey heat and electricity in more than one direction. Iron radiators are frequently, though not always, colder than adjacent objects. Every submerged metal intake is a radiator conveying heat from the Lake bottom, which *never freezes* at intake depths, to any colder substance in contact—spicules of ice, for instance. If in summer the sun warms the water at the intake to a degree above that of the Lake bottom, the intake conveys heat in the opposite direction.

(The discussion with Mr. Benzenberg, above referred to, occurred about two years before house services were thawed by electric currents.)

H. F. Dunham.

New York, Feb. 18, 1910.

CONCRETE PATTERNS FOR CASTINGS were mentioned in a paper on "Modern Pattern Shops" read recently before the Pittsburg Foundrymen's Association by Mr. Joseph L. Gobeille, of Niagara Falls, N. Y. No details were given, but we give the following extract from the paper:

We wanted a shell-like casting for a gear case. We modeled this in clay and took an impression in plaster of the male side, which was to be our drag. We then made a reverse by processing, and poured a female from which we made our cope. These were poured in hardened concrete in an iron flask, allowed to dry, rammed up separately, put together and poured from hand ladles. We never had a pattern, but got a fine, perfect casting; size about 18 x 30 x 13 ins. deep, 22 indentations, bosses and oil courses, irregular in shape, ⅜-in. thick, weight 228 lbs.; cost of pattern maker's time, $9.20, and all from blue print ¼ size.

A set of patterns for 60-in. pipe bend, T-valve and end connection cost $628 and was destroyed by fire. The insurance companies settled. We replaced the patterns (from castings) in concrete for $52.

If your flasks are right you can get 100 castings from an ordinary concrete pattern, and then make a new one for less than you could patch up, varnish and store a wood pattern.

A Practical Method for Sketching Ellipses.*

BY GEORGE WETMORE COLLES.†

The number of ways given in text-books, technical journals and other sources for drawing ellipses is legion. It may seem very doubtful whether a new and better way can be devised; nevertheless, it is universally acknowledged that all the schemes generally taught are unpractical or at least unsatisfactory because they take too much time and then give but mediocre results. The following method was devised by the writer especially for his own use, and so far as he knows it is new. It is suitable for rapid and accurate work and unless a very smooth line is required, a sufficiently correct ellipse can be drawn in a few minutes entirely without the use of a curved ruler.

Most ellipses which the draftsman is called on to produce have their principal axes given; but occasionally we have a skew ellipse where the lengths of the principal axes are not known and even their directions are not readily apparent. In this case, however, we nearly always have, in mechanical drawings, a pair of conjugate axes to which the present method is equally applicable, and by its means the ellipse may be drawn without appearing "cock-eyed" or "lop-sided."

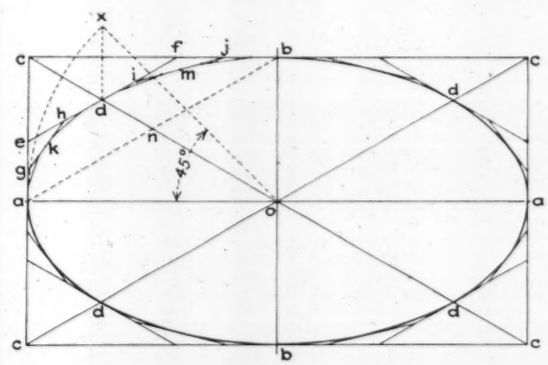


Fig. 1.

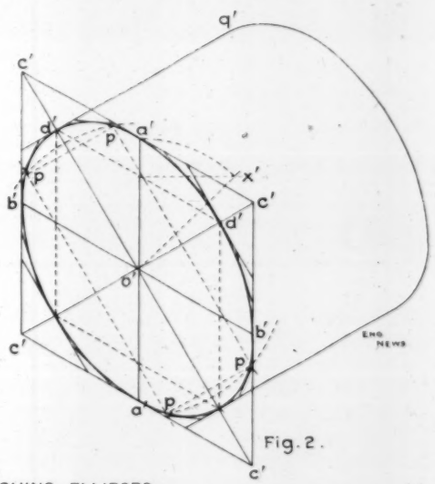


Fig. 2.

PRACTICAL METHOD FOR SKETCHING ELLIPSES.

(The line *e f*, Fig. 1, parallel to *a b*, is tangent to the ellipse at *d*. Points *i* and *j* bisect *d f* and *f b*. Line *i j*, at its midpoint *m*, is tangent to ellipse, etc.)

The point *d* as thus found and the tangent *ef* are exact, and the other tangents so nearly so that their inexactness will be visible to the eye only in very large ellipses.

For ordinary curves in practice, the point *d* can be found by mere inspection, without the geometrical construction *ox*, *xd*. Bearing in mind that *oc* : *od* equals √ 2, bisect *oc* at *n* (either by the eye or by drawing *ab*), and lay off *nd* equal to 0.41 *nc*, subsequently drawing *ef* as before. It will be found that the four points *d* can be laid off by the eye and the other lines drawn in a few minutes and then the ellipse can be sketched in free-hand with a better appearance than one drawn with a curved ruler by other methods.

In Fig. 2 the same principles are applied to a skew ellipse. In such cases, it is necessary first to find the conjugate axes. For these we may take any two lines which would be at right angles were the circle viewed full face, which can be readily found in the case of a perspective drawing; for example, we may take the two principal axes of projection in the plane in which the ellipse lies. Upon these axes *a' a'*, *b' b'*, describe the enclosing rhomboid *c' c' c' c'*, lay off *d'* in each quadrant, dividing the line *c' o'* in the same proportion as *co* in Fig. 1 in each case, and proceed as before. This does not give the principal axes of the ellipse, but when the ellipse is once drawn, these axes are easily found by describing a circle *pp* about *o'* as a center, intersecting the ellipse in four points which are symmetrical to the principal axes. The sides of the rectangle formed by joining the four points *p* will be parallel to the principal axes.

In an isometric projection of a cylinder, the major axis is at right angles to the limiting elements *d' q'* which are tangent to the ellipse at its ends.

Most methods fail because they only give points upon the curve, ignoring the fact that the *direction* of the curve at the point is fully as important as the point itself. The envelope methods which have been devised, however, are not usually practical because they do not apply themselves readily to the particular ellipse which one wishes to draw. The present method is based on the fact that every ellipse may be considered a strained circle, that is, one which is distorted in one or two directions proportionately at all points.

The accompanying drawings, Figs. 1 and 2, show the method as applied to right and skew ellipses. In Fig. 1, *aoa*, *bob*, are the principal axes intersecting at *o*. Upon these construct the rectangle *cccc* tangent to the ellipse at *a* and *b*. Draw the diagonal *cc*, *cc*. Draw *ox* at 45° with axis *aa*, lay off upon it *ox* equal to *oa*, and drop the perpendicular *xd* to the axis *aoa*, intersecting *oc* at *d*, which is a point upon the ellipse, and the tangent *edf* is drawn parallel to *coc*. In small ellipses, the three points and tangent on each quadrant will be sufficient to enable the ellipse to be constructed satisfactorily, but for greater exactness bisect *ae* and *ed* at *g* and *h*, and *df* and *fb* at *i* and *j*; then the lines *gh* and *ij* will be tangent to the ellipse, and will practically draw the curve, but if this is still insufficient we may bisect *gh* at *k* and *ij* at *m* and again bisect *ag*, *gk*, *kh*, *hd*, *di*, *im*, *mj* and *jb*, joining the points of bisection to give further tangents to the curve.

*A method of constructing an approximate ellipse with eight circular arcs and a graphical method of measuring the curved length was described in Eng. News, April 4, 1907, p. 388.

†404 Alhambra Bldg., Milwaukee, Wis.

A REVISION OF THE NATIONAL FOREST RESERVATION boundaries has been agreed upon between Secretary Wilson of the Department of Agriculture and Secretary Ballinger of the Interior Department. The following are to be retained within the reservations:

1. Lands wholly or in part covered with brush or other undergrowth which protects stream flow or checks erosion on the watershed of any stream important to irrigation or to the water supply of any city, town or community, or open lands on which trees may be grown, unless the permanent value of such lands under cultivation is greater than their value as a protective forest.

2. Lands wholly or in part covered with timber or undergrowth, or cut-over lands which are more valuable for the production of trees than for agricultural crops, and lands densely stocked with young trees having a prospective value greater than the value of the land for agricultural purposes.

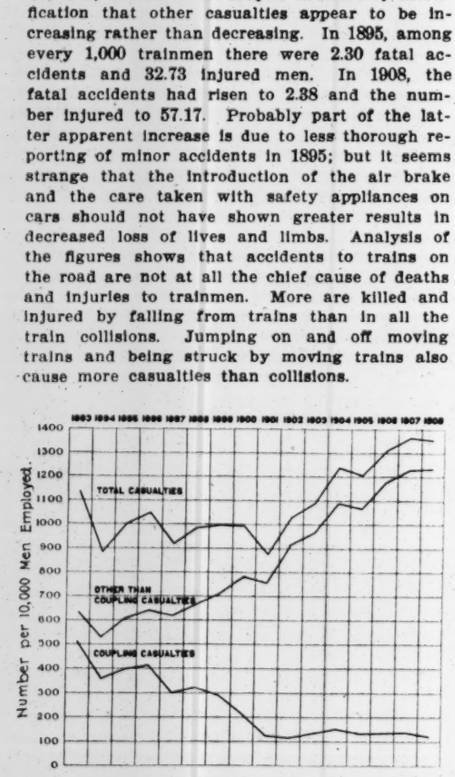
3. Lands not either wholly or in part covered with timber or undergrowth, which are located above timber line within the forest boundary or in small bodies scattered through the forest, making elimination impracticable, or limited areas which are necessarily included for a proper administrative boundary line.

Lands not either wholly or in part covered with timber or undergrowth, except as provided for in the preceding paragraphs, upon which it is not expected to grow trees, are to be eliminated from the national forests.

Casualties to Railway Trainmen.

The Interstate Commerce Commission has published some recent statistics of the casualties to railway trainmen accompanied by a diagram which we reproduce herewith. The gratifying thing in these statistics is that the casualties in coupling cars have been greatly reduced. In 1893, when a part of the cars in service had old link and pin couplers and a part had M. C. B. couplers, the trainman's work in car coupling was at about its most dangerous stage, and in a year's time one man in every 20 trainmen would be hurt in coupling cars. Since 1901 the casualties in coupling cars has been fairly steady, with about one man injured or killed per annum for every 80 trainmen.

But our gratification at the lives and limbs saved by the M. C. B. coupler is offset by mortification that other casualties appear to be increasing rather than decreasing. In 1895, among every 1,000 trainmen there were 2.30 fatal accidents and 32.73 injured men. In 1908, the fatal accidents had risen to 2.38 and the number injured to 57.17. Probably part of the latter apparent increase is due to less thorough reporting of minor accidents in 1895; but it seems strange that the introduction of the air brake and the care taken with safety appliances on cars should not have shown greater results in decreased loss of lives and limbs. Analysis of the figures shows that accidents to trains on the road are not at all the chief cause of deaths and injuries to trainmen. More are killed and injured by falling from trains than in all the train collisions. Jumping on and off moving trains and being struck by moving trains also cause more casualties than collisions.



Casualties to Railway Trainmen from 1893 to 1908.

The Interstate Commerce Commission attempts to explain the cause of increased casualties by declaring that "the duties of trainmen are each year becoming more severe and exacting." In support of this it presents a diagram showing that the tons of freight carried one mile per trainman employed have increased from 510,000 in 1893 to 770,000 in 1908. This does not necessarily involve added risk to trainmen, however. It means simply that the average weight of freight trains has greatly increased. In 1893 the average freight train carried 184 tons of freight. In 1908 it carried 352 tons. It is this that has enabled the railways to pay higher prices for everything they use in operation without raising rates of fare and freight.

We believe, if a thoroughly competent bureau for accident investigation were established at Washington, such as the Commission itself has repeatedly advocated, a way would be found to cut down the present high rate of casualties to employees.

Notes from Engineering Schools.

UNIVERSITY OF KANSAS.—The dedication of the new engineering buildings, comprising the engineering hall, mining building and the combined mechanical laboratory and power plant, will occur on Feb. 25. Among the speakers will be President R. C. Maclaurin, of the Massachusetts Institute of Technology and Mr. E. R. Buckley, President of The American Mining Congress.

STEVENS INSTITUTE OF TECHNOLOGY.—At the ninth annual dinner of the Alumni, held in New York City, Feb. 12, President A. C. Humphreys announced that $63,500 had been received of the $1,250,000, which he expected to raise for the improvement and extensions of the Institute. The projects included in this development were, the purchase of the Castle Point estate, the erection of a dormitory of a mechanical laboratory and of an electrical laboratory, and the establishment of an endowment fund.

It was stated that $400,000, was immediately required, and it was expected would soon be raised, for paying a debt still remaining on the athletic field and for acquiring real estate necessary for the more immediate needs of the Institute.

RENSSELAER POLYTECHNIC INSTITUTE.—At the meeting of the general alumni association held at the Plaza Hotel in New York City, Feb. 4, announcement was made that the Pittsburg alumni association had presented to the board of trustees of the Rensselaer Polytechnic Institute the sum of $125,000 for the purpose of building a new library and administration building. Mr. William G. Wilkins, M. Am. Soc. C. E., of the class of '79, of Pittsburg, is to prepare the plans of the building, which will be constructed during the present year. It will be built of Harvard brick and Ohio sand-stone to conform to the other new buildings on the institute campus and will contain offices of the president and treasurer beside reading rooms and stack room capable of holding about 200,000 volumes.

COLUMBIA UNIVERSITY.—Announcement has been made of an extension of classes, in electrical and mechanical engineering, architecture, preventive medicine and sanitary science, manual training and household arts, law, teaching, economics, history, literature, etc., to be held at Columbia University and at various parts of New York City and northern New Jersey. For this work a large staff of professors and lecturers will be appointed, chosen in part from the present teaching staff of the University and in part from others with special fitness for work of this kind. The whole undertaking will be under the supervision of Prof. James Chidester Egbert, who will serve as Director of Extension Teaching. Plans for the organization of this undertaking are going rapidly forward, and those who wish to have classes organized in any given part of the city or in a given community, are requested to address Prof. Egbert at Columbia

A POWDER MILL EXPLOSION Feb. 17 in the mixing room of the Trojan Powder Works at San Lorenzo, Cal., started a fire which destroyed ten of the 25 buildings making up the plant. Five men were killed and four others were badly injured.

RESPONSIBILITY FOR THE EXPLOSION in the Ernest coal mine near Indiana, Pa., noted in our issue of Feb. 10, has been placed by a coroner's jury upon the Jefferson & Clearfield Coal & Iron Co., owner of the mine. A fire-boss, a mine foreman and a superintendent are charged in the verdict with not having complied with the Pennsylvania state laws governing the operation of bituminous mines. A mine inspector is charged with laxness and negligence. The explosion was found to have been caused by the ignition of gas by an open lamp.

UTILIZATION OF FIRE DAMP IN A COAL MINE in Germany is noted as follows in a recent issue of the "Mining and Scientific Press":

Gas in frequently found in coal mines, but is usually considered only as a dangerous material to be driven out as promptly as possible. In one of the collieries of the Frankenholz Mining Co. in the Sarrebrück basin of Germany, "fire damp" has been saved and used as fuel. It was discovered in a diamond-drill hole while prospecting underground. Finding after a few days that the flow did not diminish, a pipe was fitted into the hole and the gas conducted to the surface for use under boilers. When the supply showed signs of diminishing a parallel hole was drilled about 35 ft. distant and an additional supply under good pressure was found. "Blowers" of inflammable gas are not uncommon, being occasionally found even in metal mines, as at Silver Islet in Lake Superior. It is probable that they might be used more often, thus changing them from sources of danger into a valuable asset.

THE WRECK OF THE STEAMER "LIMA" in Huamblin Passage of the Straits of Magellan, noted our last week's issue, has turned out to be very m less disastrous to human life than seemed likely fr the early reports. A cruiser of the Chilian Navy, s to the scene of the wreck succeeded in rescuing on F 15 all of the 88 persons which the "Hatumet" had b obliged to abandon. The cruiser was the "Minis Zenteno," which represented the Chilian Government the Jamestown exposition.

A DERAILMENT CAUSED BY A SHIFTED C wheel occurred on the London, Brighton & South Co Ry. (England) at Stoat's Nest on Jan. 29. A fast p senger train for London was approaching the station a was passing over a turnout when the front truck the fifth car left the track at the crossing frog. The turned crosswise to the track and slid up the incli forming the end of the station platform, carrying aw a water column and being overturned upon its side. T sixth car was derailed but none of the other cars l the track. Seven persons were killed and nine or t injured. The signalman at the cabin opposite the ju tion reported having seen showers of sparks comi from the leading truck of the wrecked car. Investigati showed that one wheel on the front axle of this tru had shifted outwards on its journal about an inch, a had ground deeply into the truck frame. The whe flange evidently struck the point of the crossing fr and got on the wrong side of the frog, twisting t truck out of line and causing the car to swing acro the tracks. In the account of the accident in the "E gineer" (London) the remarkable (but erroneous) stat ment is made that fixed frogs "do not exist in Am ica," movable-point frogs being used instead. As a matter of fact, movable-point frogs are used mainly where the angle of crossing is 8° or less. It was stated at the coroner's enquiry that the wheels were pressed on at a pressure of 60 tons.

A BROKEN RAIL is reported to have derailed a pa senger train on the Chicago & Northwestern Ry. near Green Bay, Wis., on Feb. 19, injuring 14 persons. One sleeping car was overturned and had to be broken into to rescue the passengers. Two other sleeping cars were badly smashed and the smoker was reported thrown a few hundred feet from the track.

A freight engine, running free on the Wheeling and Lake Erie R. R., broke through a trestle about 15 miles from Wheeling, W. Va., Feb. 19. The fireman was killed and the engineer and two trainmen were injured—probably fatally.

A freight train was derailed at Layton tower, west of Connellsville, Pa., on Feb. 17. The engine turned over, injuring the fireman and engineer. A section gang was replacing a broken rail and the section hand, sent back to flag approaching trains, became confused and failed to give warning.

A boiler on a locomotive of the St. Louis & San Francisco R. R. exploded on Feb. 18, about a mile northeast of Joplin, Mo. The engine had been regularly used in the Joplin yards, but was equipped with a snow plow and sent out to remove drifts on the Carterville branch line. The engineer and conductor were killed and the fireman was fatally injured. Low water is reported to be the cause.

Through misunderstanding a gateman's signals at Sharon, Pa., a trolley car was run in front of a freight train which was backing towards a street crossing. Some 20 persons were more or less severely hurt.

An interurban electric car, on the Pittsburg, Harmony, Butler & New Castle line, left the rails on a heavy grade at New Castle, Pa., and plunged over a 150-ft. embankment and struck two cars, loaded with rock, on a railway below. One man was killed and 20 persons were injured.

THE TYPHOID DEATH RATE OF CONNECTICUT for the year 1909 was 14 per 100,000 as compared with 18, 20 and 22, respectively, during the three previous years, a rate of about 40 twenty years ago. The total of typhoid deaths was 154. This is in marked contrast with the 1,422 deaths from tuberculosis, giving a rate of 134 per 100,000.

THE TYPHOID DEATH RATE IN NEW YORK STATE in 1909 was 15 per 100,000. This was the lowest record for the State ever recorded. The total number of deaths was 1,309; 66 fewer than in 1908. The total number of deaths from tuberculosis of all kinds was 16,060, or 11.5% of all the deaths in the State.

TYPHOID FEVER in Montreal has declined to or near the normal, according to statements by Dr. Laberge, city health officer, who states that the cases have fallen to 27 in a single week as compared with 272 for the week ending January 2d. The plant to disinfect the city water supply was put in operation early in February. A little before that a similar plant was installed by the Montreal Water & Power Co. which supplied a portion of the city and some of its suburbs. Hypochlorite of lime is used in each case.

THE CLEVELAND STREET RAILWAY REFERENdum vote on Feb. 17 was in favor of the so-called Tayler 25-year franchise to the Cleveland Railway Company by 17,307 to 19,197, thus giving a majority of 8,110. The franchise limits the rate of fare to a figure that will be a dividend of 6% on an agreed valuation of the property of the company, which valuation is named in the franchise. A trial of what is approximately a 3-ct. fare will be made for a period of eight months. If this does not prove sufficient to give 6% dividend, then the rate of fare will be raised subsequently. At the same election the citizens voted against bonds for a $2,000,000 viaduct over the Cuyahoga River and a $2,400,000 city hall.

A BILL REQUIRING A STATE LICENSE for civil engineers practicing in New York was introduced in the Assembly on Feb. 18 by Assemblyman Edward J. Galdiris, of New York City. The bill creates a State Board of engineering examiners of nine members, to be appointed by the Regents. The practice of engineering is prohibited without licensing as provided in the bill. Provision is made for the licensing without examination of engineers already in the profession.

THE GEORGIAN BAY CANAL PROJECT has been indefinitely postponed by the Canadian Government, according to announcement made in Parliament on Feb. 14. The responsible officers of Government held that the financial burdens already assumed by Canada in connection with the development of transportation lines were such as to forbid undertaking the canal at present. It was also definitely stated that private companies would not take up the enterprise without a guarantee of interest by the Government.

CONDITIONS GOVERNING THE EXTENSION OF water-works mains are being investigated by a committee of the New England Water Works Association, the chairman of which is Mr. Charles W. Sherman, M. Am. Soc. C. E., 14 Beacon St., Boston. The committee has prepared an inquiry blank which requests information regarding the control of the water-works plant, the authority which decides when extensions shall be made, particulars regarding required guaranty from abutting property owners, and items of cost that are to be included in such guaranties. The inquiry blank has been sent to all members of the Association, and will be sent to any others who are willing to make response.

THE MEMBERS OF THE AQUEDUCT COMMISSION of New York City have been removed by Mayor Gaynor, and in their place commissioners have been appointed with instructions to wind up the affairs of the commission. The commission was originally created by a Legislative act passed in 1883. Its first work was the construction of the new Croton Aqueduct. This was followed by the building of the New Croton Dam, and later on by the Cross River and Croton Falls Dams. For some years past there has been a strong movement in some quarters to have the work of the commission brought to a close, but the commission showed no disposition to terminate its own existence. Instead, it prepared plans for the so-called Patterson Reservoir in the Croton drainage area, alleging that a large storage could be secured there some years before the introduction of the new Catskill supply, and that the water might be needed before that time in order to prevent serious water famine. Opponents of the Patterson Reservoir hold that the expense of its construction was utterly unwarranted in view of its unit cost of storage as compared with the storage that could be provided elsewhere, and also in view of the fact that the reservoir was likely to stand empty through long periods. The Commissioner of Water Supply, Gas and Electricity, who has charge of the water-works of the city after their completion and whose approval of new work carried out by the Aqueduct Commission is necessary, had let the plans for the Patterson Reservoir remain in his office without approval. The removed members of the Aqueduct Commission have served notice on the newly appointed members that they will contest the legality of the Mayor's act of removal and appointment of successors.

FOUR 18,000-HP. HYDRAULIC TURBINES have recently been installed in the generating station of the Great Western Power Co., on the Feather River at Oroville, Cal. A general description of these turbines and of their testing appears in the "American Machinist," Feb. 17. Each turbine is a vertical-shaft, inward-flow, Francis type with a single bronze runner designed for 525-ft. head, and a speed of 400 r. p. m. Water is delivered to the runner from a cast-steel volute casing, through guide vanes arranged around the periphery of the runner. Each guide vane carries a long shank which extends through a stuffing box and two bearings for connection to a ring operated by the governing mechanism. This ring is moved by two pistons, mounted on the casing and connected, in parallel, to the main valve of the governor. The shaft runs in two babbitted guide bearings; one of these is a part of the head cover and the other is midway between the turbine and the generator. Directly above the second guide is the oil thrust bearing which supports the revolving parts of both turbine and generator—in all about 145,000 lbs. The first unit was placed in service in December, 1908, and no signs of erosion of the vanes have yet been noted.

In the efficiency tests, the volume of water was determined by Pitot tube measurements and the pressure head was found by piezometers. The power output was found by using the generator as a brake, delivering measured current to a water rheostat. The maximum efficiencies obtained were as follows: Unit No. 1, 87% at 87% load; Unit No. 2, 87% at 90% load; Unit No. 3, 88.2% at 93% load; Unit No. 4, 89% at 91.5% load. The actual head during test was only 420 ft. owing to incompletion of the head works. Full load was taken as 14,000 HP. (the designed full-load condition for the reduced head). The turbines, complete with governors, were designed and built by the I. P. Morris Co., of Philadelphia.

A SUCTION OIL-GAS PRODUCER.—A small piece of apparatus known as the "Hydrocarbon Converter" has been developed to enable gasoline and gas engines to use petroleum residue, from which the gasoline, kerosene and similar light oils have been distilled. This converter takes in the heavy residues with a deficient supply of air and "cracks up" the oil to a gas, the composition of which (by volume) is stated as:

CO_2	7.6
O_2	1.2
"Illuminants"	9.4
CO	3.1
CH_4	7.5
H_2	1.9
N	69.3
	100.0
B. T. U. per cu. ft.	286.

The field of the invention is not limited to the use of heavy residues only. It gasifies kerosene even more easily.

The generator consists of a nest of cast-iron cylinders forming three compartments, one within another. The generator is connected to the engine and to the oil supply, much like an enlarged carburetter. The engine exhaust is piped to the middle compartment; the hot gases circulate here and finally pass out through a final exhaust. The outer and inner chambers are heated at first by the exhaust gases, but when the generator is in full operation sufficient heat is developed by the partial combustion of the oil so that the engine exhaust serves more to restrict excessive radiation. Air is introduced into the outer chamber, where it is highly heated. It is then drawn through a pipe which joins one from the oil supply and there is drawn into the inner compartment, by the suction of the engine, a mingled stream of oil and hot air. The inner compartment contains nested shells of crucible material which is of a minutely porous character. The hot porous shells absorb the oil and by capillary action divide it into microscopic particles of much smaller size than can be made by spraying. The oil thus minutely subdivided is completely gasified by the heat of the cell walls and is not merely vaporized. The gas is drawn from the inner compartment and passed directly to the cylinder of the explosion engine, without need of scrubbing or purifying.

Test of this apparatus was made by Mr. J. L. Bogert, C. E., of New York City, as connected to a 70-HP. engine on the yacht "Wayward" in Sept., 1909, after a test of the engine on gasoline fuel. The following data were obtained:

	With gasoline.	With crude oil.
Date, 1909	Sept. 14.	Sept. 13.
Distance over course, miles	80	80
Condition of weather and tide	same	same
Time of run, hours	8	7 5/6
Gals. of fuel used	97	40
Gals. per hr.	12.125	5
Pints per B.H.P.-hr.	1.39	0.57
Cost per gal.	$ 0.14	0.03
Cost of fuel per hr.	1.697	0.15
Cost of fuel per B.H.P.-hr.	0.024	0.002
Cost of fuel per run	$13.58	$1.20

Tests now being made on a gasoline-electric railway motor car show quite similar results as to cost of operation.

It is proposed to use this gas generator for oil-fired boilers. In this case the outer and middle compartments are unnecessary and a type, having only the gasification chamber, is mounted directly on the bridge wall. The oil is fed to the porous shells without air and the gas is led off to be burned as desired. It is proposed to make illuminating gas in a similar way. An average analysis (by volume) of the gas made without introducing air is given as follows:

Illuminants	36.9
CO	3.1
H_2	6.6
CH_4	53.4
	100.0
B. T. U. per cu. ft.	1,342.

This invention is being financed by Thos. Nevins and Son, 37 Wall St., New York City.

A SHIP CANAL ACROSS SCOTLAND is projected but its promoters find it difficult to make out prospective profits sufficient to attract capital. According to "Engineering" of Jan. 28, the British Admiralty have decided that while the canal "would unquestionably possess some strategic value," it would not be of enough advantage "to warrant any considerable expenditure from Government funds or such liability as a guarantee of interest on the total estimated cost of construction." Thus while some Government aid is probable, in case the canal is made large enough for battleships, the enterprise must rely on its commercial earnings in its appeal to capitalists.

The canal as surveyed would extend from the Firth of Forth to the Clyde via Loch Lomond. The estimates of cost for a canal of 36-ft. depth and 100-ft. width are $100,000,000, but the Admiralty require a width of 148 ft. if the canal is to meet naval requirements. The estimates of probable traffic made by the promoters are claimed to show a total of 5 to 7 million tons per annum. With tolls of about 35 cts. per ton, "Engineering" computes that this would yield 2 to 2½% on the cost of construction. In making this estimate, however, the cost of maintenance and operation is left out. As our contemporary well says, the problem of financing the scheme is one of almost insurmountable difficulty.

THE COST OF OPERATING THE MUNICIPAL asphalt plant at San Francisco during the month of December, 1909, is summarized in the "Municipal Record," the official journal of the city, Jan. 27, 1910, as follows:

WORK AT PLANT.

	Cu.ft. of Mixture.	Cost of Material Incorporated.
Wearing surface	15,068	$4,076
Binder	16,800	2,301
Labor at plant	.....	1,809
Repairs, oil, fuel, etc.	.....	1,581
Totals	32,468	$9,769

WORK ON THE STREET.

	Cost of labor and Teaming.	Sq. ft. Laid.	Cost per sq ft.
General repairs (roving gang)	$3,399	107,101	$0.0317
North Beach District	607	18,764	0.0324
Totals	$4,007	125,865	$0.0318
Total cost of material to street			$9,769.26
Total number of square feet laid			125,865
Cost per square foot for material			$0.0776

	Cost of Labor per sq ft.	Cost of Material per sq ft.	Total Cost per sq. ft.
General repairs	$0.0317	$0.0776	$0.1093
North Beach District.	0.0324	0.0776	0.11
Mean average cost per square foot in all locations			$0.1094

BUILDING GATUN LOCKS.—The first monolith in the east wall of Gatun Locks was completed last week, and work is in progress on two more. Three forms for the center wall monoliths are in process of erection. The sill of the emergency dam above the west lock is completed, and the sill above the east chamber is about three-fourths finished.

Excavation in the forebay of the locks is finished, and the floor in the forebay is almost completed. In the second locks, one of the steam shovels, excavating for the foundations, is at grade, 18 ft. below sea level.

The amount of concrete placed in the locks during the week ending Jan. 29, was 14,165 cu. yds., the greatest amount that has been placed in any week since the work was begun. On Jan. 25, 2,764 cu. yds. were placed, the largest amount placed in one day up to that time. The record by days follows:

	Cubic yards.
January 24	2,258
January 25	2,764
January 26	2,392
January 27	2,128
January 28	2,025
January 29	2,598
Total	14,165

The record by months follows:

	Amount; cu. yds.	Average per day; cu. yds.
August (seven days)	1,298	185
September (26 days)	12,294	473
October (31 days)	29,378	948
November (24 days)	30,270	1,261
December (26 days)	42,832	1,647
January 1 to 8 (6 days)	11,065	1,844
January 10 to 15 (6 days)	12,480	2,080
January 17 to 22 (6 days)	12,943	2,157
January 24 to 29 (6 days)	14,165	2,361
Total	166,825	1,209

—From the "Canal Record," Feb. 2.

THE COMPARATIVE EFFECT OF MOTOR AND HORSE-DRAWN VEHICLES ON ROADS.—We can build a road that will perfectly suit horse traffic, or we can build one that will perfectly suit motor traffic, but no type of construction has been devised for satisfactorily meeting both classes of traffic. Roads built of brick, concrete, bituminous materials and the various dust inhibitors are subjected to little or no wear from motor traffic, but are worn out by the action of horses' feet and narrow-tired, overloaded horse vehicles. Besides, these types of hard pavements are quite injurious to horses. Recently I addressed the following question to

all of the State Highway Commissions and a number of highway engineers: "At what rate of speed do you consider motor vehicles to be more injurious to the ordinary macadam road than horse-drawn vehicles?" Answers have been received from about one-half, and the majority of these experts state that at speeds not exceeding 20 miles an hour motor traffic is not more injurious to the ordinary macadam road than horse traffic. There are laws in almost every locality in this country designed to limit the speed of automobiles to a sufficient extent to prevent their seriously damaging the road, but nowhere that I know of are these laws enforced, nor do I believe it practicable to enforce them. If we cannot control the speed of motor traffic in the infancy of the motor era, how can we expect to cope with it in the future, when we consider that cars are being manufactured now at the rate of about 10,000 a month? Wherever a road exists with a smooth, hard surface, the horse should be outclassed by the motor vehicle in the transportation of commodities to markets and shipping points. I do not believe it too prophetic to say that motor transportation from the farm to the market will contribute much to lessen the cost of food. As an example of this, large supplies of food products from the territory surrounding London are transported to the city in trains of cars drawn by traction engines, and these trains return to the farms with manure and other necessary supplies. The value and economy of motor transportation in cities for freight has been demonstrated, and the economy of building roads over which it can travel in the country will become more and more evident to the taxpayers in rural districts. Already the farmers are becoming owners of motor cars, and when this conservative element of our population utilize to the fullest extent the advantages offered by the motor car for business purposes, much of the prejudice and many of the faults attendant upon the present opening Automobile Era will disappear. Extracts from an address by Logan Waller Page, Director, Office of Public Roads, delivered at National Legislative Convention, Washington, D. C., Feb 15, 1910.

ASPHALT PAVEMENT CONSTRUCTION AND REpairs by day-labor instead of by contract is authorized in a bill which has been favorably reported by a committee of the Ohio legislature. The bill was introduced at the instance of the city authorities of Columbus, Ohio. Another bill before the legislature extends the above-named authority to other kinds of pavement.

PRISON SEWAGE DISPOSAL FACILITIES in a prison built by the German Government at Lüttringhausen, near Elberfeld, to accommodate 553 male prisoners is described in "Zeitschrift für Bauwen" for Jan. 3, 1910. The contents of the pails provided for the cells are taken to a covered compost shed, where they are prepared for use on agricultural land. The pails are washed in a wash-room, provided with sinks having large discharge pipes. The wash-water is first treated in a so-called biological purification plant, which appears to include tanks and filters, and is then used to irrigate land.

A FOREST FIRE WAGON with equipment for fighting forest fires has been placed on exhibition at 251 Causeway St., Boston, by Massachusetts State Forester Rane. The wagon and its equipment is described in the Boston "Transcript" as follows:

In the main the fire-fighting outfit consists of a wagon, extinguishers, water cans, chemicals, shovels, axes and hoes, and nearly all of these articles have been constructed especially for the forest fire service. The wagon is light, with broad-tired wheels. There are 14 extinguishers and as many more double-charge water cans, arranged conveniently along the sides, so that 42 charges are available for an uninterrupted assault on a fire as soon as the wagon arrives at the spot. Besides this there are 12 water cans on the running board in the rear, and boxes conveniently arranged on shelves near the end for 96 extra charges of soda and vitriol. Hence should the wagon be needed for carrying water, all the chemicals and a generous original supply of water may be taken off and operated without interruption. Stored away in convenient corners are the grub hoes, shovels and axes which are always necessary in this work. Moreover, this wagon is equipped with a can of novel construction which has not been in the market before, and is intended to expedite the back-firing which must be practised when a forest fire is gaining headway. This can does away with the slow process of gathering leaves and papers in which to start a line of fires, as it will give out a fine spray of kerosene by means of compressed air which is pumped into it by hand. A man can swing this can over his shoulder and spin out a line of fire about as fast as he can run.

The object of the exhibition is to stimulate the interest of local authorities in fighting fires and in providing a proper equipment for the work.

Personals.

Mr. E. M. Alvord, General Superintendent of the Missouri, Kansas & Texas Ry., with headquarters at St. Louis, Mo., has resigned to become General Manager of the Midland Valley R. R.

Mr. A. O. Rowse, M. Am. Soc. C. E., U. S. Assistant Engineer at Sterling, Ill., has been appointed to take charge of the work of deepening the Des Moines River from Des Moines to Keokuk, Iowa.

Mr. Roy V. Wright, M. Am. Soc. M. E., who has been for some years Managing Editor of the "American Engineer and Railway Journal," has become a member of the editorial staff of the "Railway Age Gazette."

Mr. H. M. Chapin and Mr. T. J. Bryson, both recently with the Cambria Steel Co. at Johnstown, Pa., have opened an office for the practice of architecture and civil engineering in the Nettleton Bldg., Ashtabula, Ohio, under the firm name of Chapin & Bryson.

Mr. Wm. C. Smith, M. Am. Soc. C. E., formerly Chief Engineer of the Idaho & Washington Northern R. R., with headquarters at Spirit Lake, Idaho, has been appointed Chief Engineer of Maintenance of Way of the Northern Pacific Ry., with headquarters at St. Paul, Minn.

Mr. John M. Ewen, M. Am. Soc. C. E., has resigned from his position as Harbor Commissioner of the city of Chicago. In his letter of resignation he gives as the cause of his action, his belief that future harbor and dock development should be under the control of the Sanitary District—a view not shared by the present city administration.

Mr. Arthur Underhill has resigned his position as landscape engineer of the Board of Water Supply of New York City, which he has held for a number of years, in order to devote himself entirely to private practice. Mr. Underhill is a graduate of Cornell University, and is a member of the Municipal Art Commission and the Shade Tree Commission of Montclair, N. J., where he resides.

Mr. J. M. Wakeman, Assoc. Am. Inst. E. E., Vice-President of the McGraw Publishing Co. and General Manager of the "Electrical World," has resigned those positions and will retire for a time at least from active business. Mr. Hugh M. Wilson has resigned his position as Vice-President of the Barney & Smith Car Co. to succeed Mr. Wakeman as Vice-President of the McGraw Publishing Co. Mr. Wakeman has been Vice-President of the McGraw company since its incorporation in 1899. He will not immediately retire, but will continue for some months as a director of the company. Mr. Wilson, before becoming Vice-President of the Barney & Smith Car Co., was the publisher of the "Railway Age" and the "Electric Railway Review."

Mr. D. C. Henny, M. Am. Soc. C. E., Consulting Engineer of the United States Reclamation Service, with headquarters at Portland Oregon, has tendered his resignation in order to accept a more lucrative practice on general consulting work. He will continue his formal connection with the Service on a per diem basis as Consulting Engineer, to be available occasionally for consultation by the Reclamation Service on matters with which he is familiar. Mr. Henny graduated from the State Polytechnic School at Delft, Holland, in 1881, and was engaged on railroad and drainage work in Holland until 1884. He was thereafter engaged on railroad and water-works construction in this country until 1890. For two years he was in independent irrigation practice in Colorado, Wyoming and Utah. For a year he was general manager of the Excelsior Wooden Pipe Co., of San Francisco. This was a contracting concern building pipe lines and related works in this country, Hawaii and Alaska. In 1903 he became general manager of the Redwood Manufacturer's Co., which absorbed the Excelsior company. He constructed, for this concern, its mills, power plant, wharves, railroad yards, and water and sewage systems. During this period he was President of the Technical Society of the Pacific Coast for two terms. He joined the Reclamation Service in 1905 as Supervising Engineer for Northern Oregon and Washington. This district was subsequently enlarged to include all of Oregon, northern California and Nevada.

Obituary.

Edward A. Bowser, Professor of Mathematics and Engineering in Rutgers College from 1871 to 1904, died in Honolulu, Hawaii, on Feb. 22. He was born at Sackville, N. B., Canada, in 1845, and graduated from Rutgers in 1868. Prof. Bowser was the author of several well-known mathematical treatises.

James Gall, Jr., a well-known landscape engineer, died from paralysis on Feb. 19, at his country home near Paterson, N. J. His professional work began with the late Col. Geo. E. Waring, in the planning of Central Park, New York City. He was a veteran of the Civil War and laid out national cemeteries at Chattanooga, Tenn.; Newport News, Va.; Gettysburg, Pa., and Washington, D. C. He retired from active work several years ago.

James H. Blessing, M. Am. Soc. M. E., President of the Albany Steam Trap Co., and Mayor of Albany, N. Y., in 1899 and 1900, died in that city on Feb. 21, at the age of 73 years. He was born at French's Mills, N. Y., but had lived in Albany since he was five years old. He was trained as a machinist and in the Civil War as an Assistant Engineer, U. S. Navy. He was an inventor of numerous steam engineering appliances, manufactured by the concern of which he was president.

Edward J. Randall, Engineer of Maintenance of W of the Union R. R., at Port Perry, Pa., died at home Feb. 11. Mr. Randall was born in 1860 and educated at St. Francis Xavier College in Nova Scot of which he was a student in the year 1877-78. He e tered railway service in 1880 as a rodman in the eng neer corps of the New York & New England R. R. continued as a leveler and transitman with various ra ways and in 1887 became an Assistant Engineer of Toledo, St. Louis & Kansas City R. R. During the ne four years he held similar positions with the Lake Sho & Michigan Southern Ry. and the Denver & Rio Gran R. R. He became Engineer of the Toledo, St. Louis Kansas City R. R. in 1892, and in August, 1900, wh that road became the Toledo, St. Louis & Western R. he was made Engineer of Maintenance of Way. He w later Land and Tax Agent of the same railway for few months, but left it in September, 1901, to take th position of Principal Assistant Engineer of the Besse mer & Lake Erie R. R. He held this position unt May, 1906, when he was appointed to the post he occu pied up to the time of his death.

Engineering Societies

COMING MEETINGS.

AMERICAN INSTITUTE OF MINING ENGINEERS.
March 1-5. Annual meeting at Pittsburg, Pa. Secy R. W. Raymond, 29 West 39th St., New York City.

ILLINOIS WATER SUPPLY ASSOCIATION.
March 8-9. Annual meeting at University of Illinois Champaign, Ill. Secy., Edward Bartow, Urbana, Ill.

AMERICAN RAILWAY ENGINEERING AND MAINTE NANCE OF WAY ASSOCIATION.
March 15-17. Annual convention at Chicago, Ill. Secy E. H. Fritch, 902 Monadnock Block, Chicago, Ill.

AMERICAN WATER WORKS ASSOCIATION.
April 26-30. Annual convention at New Orleans, La Secy., J. M. Diven, 14 George St., Charleston, S. C.

APPALACHIAN ENGINEERING ASSOCIATION.
May 6-7. Annual meeting at Winston-Salem, N. C Secy., Henry M. Payne, Morgentown, W. Va.

INTERNATIONAL RAILWAY CONGRESS.—A meeting of the International Railway Congress is to be held this year at Berne, Switzerland, from July 3 to July 16. The Congress meets only once in five years, and its last previous session was at Washington in 1905. Delegates to the Congress have already been selected by over fifty American railway companies. The government is to be represented by Messrs. Franklin K. Lane and Edgar E. Clark, of the Interstate Commerce Commission, and also by Col. H. S. Haines, Past President of the American Railway Association; Fairfax Harrison, Vice-President Southern Railway; W. A. Garrett, late General Manager of the Seaboard Air Line, and J. A. Brown, Vice-President of the Railway Equipment & Publication Co.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA.—At the regular meeting on Feb. 15, Mr. Elmer K. Hiles was re-elected Secretary for the ensuing year. A paper on "The Government Testing Station in Pittsburg," was presented by Mr. J. C. Roberts, Assistant Chief Engineer, Technologic Branch, U. S. Geological Survey.

Up to the present time the work with structural materials has been confined to reinforced concrete and the constituent materials of concrete and to the testing of various clay products in the Clay Products Bureau. During 1910 it is expected that a 10,000,000-lb. testing machine will be installed, capable of testing 65 ft. full size section columns, etc.

In the fuel investigations most of the coals from the various districts have been tested under boilers and in gas producers, and various liquid fuels have been investigated. Much work has been done with briquetting coals.

It is estimated that 200,000,000 tons of coal are wasted annually by being thrown on the culm banks, or left in the mine in pillars and otherwise. The gas producer investigations have demonstrated that highly efficient results can be obtained with the roof coal, bone coal, etc., that is usually wasted. When firing the producer with washer refuse, carrying 68% ash, full load has been carried on the gas engine.

Much work has been accomplished in connection with the investigations of the causes and prevention of mine accidents. Explosives are tested and the station has established a list of "permissible explosives" for use in coal mines. Safety lamps are tested under every possible circumstance of use as well as the various types of rescue apparatus. In the rescue and training stations now in operation at Pittsburg; Urbana, Ill.; Knoxville, Tenn.; McAllister, Okla.; and Seattle, Wash., training classes are established to educate the miners in the use of rescue apparatus and the operators are urged to send picked men to attend these classes and to establish local rescue stations in the vicinity of their mines.

An inspection trip has been arranged for Saturday, Feb. 26, when the members of the society will visit the Testing Station in Pittsburg.

Tests of explosives fired into coal dust will be made in the gas and dust gallery, and safety lamp tests and a practical demonstration of rescue work as carried out in mines will be made.